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MISSION SERVICES PROGRAM OFFICE

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Greenbelt, Maryland

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Preface

The Space Network Users' Guide (SNUG) is intended as a guide to the customer community for obtaining communication support from the National Aeronautics and Space Administration (NASA) Space Network (SN). The emphasis in the SNUG is on the interfaces between the customer and the SN.

This document is under the configuration management of the Goddard Space Flight Center (GSFC) Mission Services Program (MSP) Configuration Control Board (CCB).

Configuration Change Requests (CCRs) to this document shall be submitted to the MSP CCB, along with supportive material justifying the proposed change. Changes to this document shall be made by Document Change Notice (DCN) or by complete revision.

Questions and proposed changes concerning this document shall be addressed to:

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This document has been placed on the GSFC Centralized Configuration Management System (GSFC/CCMS). The GSFC/CCMS is accessible via the World Wide Web at:

http://gdms.gsfc.nasa.gov

The Space Network Users' Guide is also available via the World Wide Web at the following URL address:

http://msp.gsfc.nasa.gov/tdrss/guide.html

Public access via the World Wide Web to a number of documents and URL addresses referenced in this document may be restricted. Please contact the GSFC MSP for assistance with any documents to which SN customer access is denied.

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Section 1. Introduction

1.1 Purpose and Scope

1.1.1 Purpose

This document describes the customer services provided by the National Aeronautics and Space Administration (NASA) Space Network (SN) and guides the customer through the process of obtaining support from the SN.

1.1.2 Scope

The SN was established in the early 1980s to replace NASA's worldwide network of ground tracking stations. It consists of a constellation of geosynchronous satellites and associated ground systems and operates as a bent pipe relay system between customer platforms and customer ground facilities. For customer platforms operating in a low earth orbit (LEO) above 73 km in altitude, the SN is capable of providing tracking and data acquisition services over 100% of the customer platform's orbit. A more detailed description of the SN and its elements is provided in Section 2 of this guide.

The emphasis in this guide is on the interfaces between the customer and the SN. Topics covered include the following:

a. Ground interfaces between the customer Mission Operations Center (MOC) and the SN.

b. Radio Frequency (RF) interface between the customer platform and the SN.

c. Procedures for working with the Goddard Space Flight Center (GSFC) Mission Services Program (MSP), which has the management and operational responsibility for the SN, to establish customer interfaces.

d. The capabilities, service characteristics, and operational aspects of the SN.

e. Generalized capabilities and technical characteristics of non-SN elements that support the SN customer.

1.2 Additional Information

The SN is constantly evolving. Circumstances may exist in which SN customers need more information than is provided in this document and in the referenced documents. SN customers are encouraged to directly contact the GSFC MSP for further information. The GSFC MSP web page can be found at http://nmsp.gsfc.nasa.gov/.

1.3 Document Organization

This document is organized as shown in Table 1-1.

Table 1-1. Document Organization

Section/ Appendix	Title	Purpose
1	Introduction	Provides an introduction to the SN Users' Guide. Describes the purpose, scope, and organization of the document, and provides the list of reference documents.
2	SN Overview	Describes the SN and non-SN elements that provide support during SN operations, and a describes the interfaces between the SN and the customer.
3	Service Available to Customers	Briefly describes the various services available to SN customers.
4	Obtaining SN Services	Describes the process for obtaining SN services.
5	MA Telecommunications Services	Describes the Multiple Access (MA) telecommunications services available to SN customers.
6	SSA Telecommunications Services	Describes the S-band Single Access (SSA) telecommunications services available to SN customers.
7	KuSA Telecommunications Services	Describes the Ku-band Single Access (KuSA) telecommunications services available to SN customers.
8	KaSA Telecommunications Services	Describes the Ka-band Single Access (KaSA) telecommunications services available to SN customers.
9	Tracking and Clock Calibration Services	Describes the tracking and clock calibration services available to customers for MA, SSA, and KuSA telecommunications services.

Table 1-1. Document Organization (con’td)

Section/ Appendix	Title	Purpose
10	SN Operations for TDRSS Services	Provides a general description of scheduling operations, real-time operations, and customer platform emergency operations.
A	Example Link Calculations	Contains example link calculations for SN telecommunications services.
B	Functional Configurations for TDRSS Forward and Return Services with Emphasis on Customers’ Data Phase and Data Channel Ambiguity Resolution	Provides data communication functional configurations for TDRSS telecommunications services; and for these functional configurations, identifies the conditions under which either a data phase ambiguity or a data channel ambiguity may exist at the SN/customer data interface.
C	Operational Aspects of Signal and Autotrack Acquisition	Details the operational aspects associated with acquisition.
D	Spectrum Considerations	Describes some of the applicable treaty agreements on spectrum usage relevant to space missions utilizing the SN.
E	Customer Platform and TDRS Signal Parameters Definition	Contains the definitions of parameters applicable to the transmitted signal, where the forward definitions describe the signal characteristics from the TDRS spacecraft and the return definitions describe the signal characteristics from the customer platform.
F	Periodic Convolutional Interleaving with a Cover Sequence for Synchronization	Describes Periodic Convolutional Interleaving (PCI).
G	Predicted Performance Degradations Due to RFI	Describes the possible degradation to SN telecommunications services caused by Radio Frequency Interference (RFI).

Table 1-1. Document Organization (con'td)

Section/ Appendix	Title	Purpose
H	Demand Access System (DAS)	Describes the new TDRSS MA DAS capability.
I	NISN Services	Describes the networked data services provided by the NASA Integrated Services Network (NISN).
J	ELV Customer Constraints	Describes the customer constraint requirements for the S-band Expendable Launch Vehicle (ELV) class of SN customers.
K	Use of Reed-Solomon Coding in Conjunction with SN Customer Services	Describes the use of Reed-Solomon (R-S) coding in conjunction with the SN customer services.
L	McMurdo TDRSS Relay System (MTRS)	Describes the support available through the MTRS capability.
M	South Pole TDRSS Relay (SPTR) and WSC Alternative Resource Terminal (WART)	Describes the capabilities provided through SPTR and WART.
N	Network Test Services	Summarizes the methodology, configurations, resources, responsibilities, and planning activities for SN testing services.
O	Self/Mutual Interference Considerations for New Customers at 2287.5 MHz	Provides an assessment of self-interference in the SN MA environment at 2287.5 MHz.

1.4 Reference Documents

This section lists the specifications, standards, and other documents which serve as references. The most recent version of these documents should be referenced.

1. Spaceflight Tracking and Data Network Test and Simulation Support Plan, 530-NOP-STDN/TS .
2. Requirements Specification for the White Sands Complex, 530-RSD-WSC.
3. White Sands Complex (WSC) Ground Terminal Requirements for the TDRS H,I,J Era, 405-TDRS-RP-SY-011.

4. Goddard Management Instruction 8070.1A.
5. Ground Network (GN) Users' Guide, 452-GNUG-GN.
6. Space Network Synoptic Description, STDN No. 134.
7. Portable Simulations System and Simulation Operations Center Guide for TDRSS and GSTDN Users, STDN No. 101.6.
8. Goddard Space Flight Center Project Management Handbook, December 1986, GSFC Projects Directorate (Code 400).
9. STDN Operations Concepts, 451-OCD-STDN.
10. Data Encryption Standard Document, The Federal Information Processing Standard 46-2, Dec. 1993.
11. TDRS & GSTDN Compatibility Test Van Functional Description & Capabilities, STDN No. 408.
12. STDN Spacecraft RF Compatibility Test Procedures and Data Sheets, STDN No. 408.1.
13. Space Network Interoperable PN Code Libraries, 451-PN Code-SNIP.
14. JSC Doc. 07700, Vol. XIV, Space Shuttle Payload System, Payload Accommodations, Attachment 1, ICD 2-19001, Shuttle Orbiter/Cargo Standard Interfaces, Revision G, Sept. 26, 1980.
15. Avionics Interfaces.
16. CLASS ACRS/TLAS Operator's Manual and Reference, NCC 98.
17. Interface Control Document Between the Network Control Center Data System and the Mission Operations Centers, 451-ICD-NCCDS/MOC.
18. Space Network Operations Policy, STDN No. 119.
19. Interface Control Document (ICD) Between the Network Control Center (NCC)/Flight Dynamics Facility (FDF) and the White Sands Complex (WSC), 530-ICD-NCC-FDF/WSC.
20. NASA Communications (Nascom) Space Network Ground Segment Data Book (542-016).
21. POCC Capabilities Document, Volume II, MCC/Remote POCC Interface Capabilities Description, JSC-14433.
22. Nascom Interface Standard for Digital Data Transmission (NISDDT), 542-003.
23. Performance and Design Requirements and Specification for the Fourth Generation TDRSS User Transponder, 531-RSD-IVGXPDR.
24. NASA Integrated Services Network (NISN) Services Document, (NISN/001-001).
25. Space Operations Management Office Services Catalog.
26. Interface Control Document Between the Network Control Center Data System and the NASA Integrated Services (NISN)/NASA Communications (Nascom) Event Scheduling Terminal (NEST), 451-ICD-NCCDS/NEST.

27. NASA Program and Project Management Processes and Requirements, NPG 7120.5A
28. Request for NASA Space Operations Services by Non-NASA Sponsored Organizations, NPD 8430
29. Customer Commitments and Review, GPG 1310.1
30. Technical Review Program, GPG 8700.4
31. Detailed Requirements Generation Process, 450-PG-1310.1.2
32. Customer Commitment Process, 450-PG-1310.1.1G
33. Peer Review, 450-PG-87000.1.1
34. Operations Interface Procedures Between the Network Control Center and Spaceflight Tracking and Data Network Customers, 451-OIP-NCC/STDN Users.

1.5 Reference Web Sites

Web sites that have been used as reference for this document are listed in Table 1-2.

Table 1-2. Reference Web Sites

URL	Web Site Description
http://csoc-ddcs.csoconline.com/cfm/getTemplate.cfm?&theURL=/docushare/dscgi/ds.py/Get/File-21113/testing_2920	Spaceflight Tracking and Data Network Test and Simulation Support Plan, 530-NOP-STDN/TS
http://csoc-ddcs.csoconline.com/ollds/nf/cfm/objectView.cfm?&collection=Collection-4459	Requirements Specification for the White Sands Complex, 530-RSD-WSC
http://csoc-ddcs.csoconline.com/cfm/getTemplate.cfm?&theURL=/docushare/dscgi/ds.py/Get/File-19773/stdn_4962	STDN Operations Concepts, 451-OCD-STDN
http://csoc-ddcs.csoconline.com/ollds/nf/cfm/objectView.cfm?&collection=Collection-4580	STDN Spacecraft RF Compatibility Test Procedures and Data Sheets, STDN No. 408.1
http://csoc-ddcs.csoconline.com/cfm/getTemplate.cfm?&theURL=/docushare/dscgi/ds.py/Get/File-21799/ncc_5087	Interface Control Document Between the Network Control Center Data System and the Mission Operations Centers, 451-ICD-NCCDS/MOC
http://csoc-ddcs.csoconline.com/cfm/getTemplate.cfm?&theURL=/docushare/dscgi/ds.py/Get/File-19654/sn_5142	Interface Control Document (ICD) Between the Network Control Center (NCC)/Flight Dynamics Facility (FDF) and the White Sands Complex (WSC), 530-ICD-NCC-FDF/WSC
http://csoc-ddcs.csoconline.com/cfm/getTemplate.cfm?&theURL=/docushare/dscgi/ds.py/Get/File-19606/comm_3261	NASA Communications (Nascom) Space Network Ground Segment Data Book (542-016)
http://csoc-ddcs.csoconline.com/cfm/getTemplate.cfm?&theURL=/docushare/dscgi/ds.py/Get/File-21692/nisn_4896	Nascom Interface Standard for Digital Data Transmission (NISDDT), 542-003

Table 1-2. Reference Web Sites (cont'd)

URL	Web Site Description
http://www.csoconline.com/service_catalog/fy2001.html	Space Operations Management Office Services Catalog
http://csoc-ddcs.csoconline.com/cfm/getTemplate.cfm?&theURL=/docushare/dscgi/ds.py/Get/File-19642/icd_3317	Interface Control Document Between the Network Control Center Data System and the NASA Integrated Services (NISN)/NASA Communications (Nascom) Event Scheduling Terminal (NEST), 451-ICD-NCCDS/NEST
http://csoc-ddcs.csoconline.com/cfm/getTemplate.cfm?&theURL=/docushare/dscgi/ds.py/Get/File-19795/stdn_4963	Operations Interface Procedures Between the Network Control Center and Spaceflight Tracking and Data Network Customers, 451-OIP-NCC/STDN Users
http://nmsp.gsfc.nasa.gov/tdrss/new.html#loc	What's New web page from the Space Network Online Information Center Homepage
http://mmfd.gsfc.nasa.gov/prod_center/pc_frame_page.htm	Flight Dynamics Facility (FDF) Product Center web page
http://128.183.140.27/nam/wnserch.htm	Network Advisory Message Page
http://msc-docsrv.gsfc.nasa.gov/GDMS_docs/pgwi400/450-PG-1310.1.1G.pdf	MSP Customer Commitment Process, 450-PG-1310.1.1G.
http://msp.gsfc.nasa.gov/tdrss/usccs.pdf	User Spacecraft Clock Calibration System (USCCS) Users' Guide

Table 1-2. Reference Web Sites (cont'd)

URL	Web Site Description
http://msp.gsfc.nasa.gov/tdrss/return_data_delay.htm	Return Data Delay web page
http://classwww.gsfc.nasa.gov/GSAMS/	GSFC Spectrum Allocation and Management Site
http://www.ntia.doc.gov/osmhome/osmhome.html	NTIA regulations
http://www.ccsds.org/green_books.html	CCSDS 411.0-G Green Handbook on RF Frequency and Modulation Systems, Part 1, Earth Stations
http://stelwscpo.gsfc.nasa.gov/Das/index_ie.htm	DAS web page
http://msp.gsfc.nasa.gov/swsi/	Space Network Web Services Interface web page
http://forbin2.gsfc.nasa.gov/prodserv/IONET/accpol.pdf	Internet Protocol Operational Network (IOnet) Access Protection Policy and Requirements
http://csoc-ddcs.csoconline.com/cfm/getTemplate.cfm?&theURL=/docushare/dscgi/ds.py/Get/File-19781/oip_3426	Operations Interface Procedures for the McMurdo TDRS Relay System, 532-OIP-NCC/MTRS
http://csoc-ddcs.csoconline.com/cfm/getTemplate.cfm?&theURL=/docushare/dscgi/ds.py/Get/File-19774/sn_5132	White Sands Complex Alternate Relay Terminal (WART) Operations Concept
http://tss.gsfc.nasa.gov/rfsoc.htm	RF SOC and GSFC Antenna Range web page
http://tss.gsfc.nasa.gov/soc.htm	SOC web page
http://tss.gsfc.nasa.gov/ctl.htm	Compatibility Test Lab web page
http://tss.gsfc.nasa.gov/rfs.htm	TURFTS web page

Section 2. SN Overview

2.1 General

The purpose of this section is to provide a description of the interfaces between the customer and the SN, and an overview of the SN and non-SN elements that provide support during SN operations.

2.2 Customer Interfaces with the SN

There are three types of interfaces between the customer and the SN: the Customer Commitment Interface, the RF Interface, and the Operations Interface.

2.2.1 Customer Commitment Interface

The Customer Commitment Interface is the interface between the customer and the GSFC MSP Customer Commitment Office through which the customer requests SN services. The process for obtaining SN services is described in Section 4.

2.2.2 RF Interface

The RF Interface is the two-way interface between the customer platform and the SN, as shown in Figure 2-1. This interface provides for the transmission of RF signals between the customer platform and the SN. These signals are described in detail in Sections 5 through 8 for SN telecommunications services and in Section 9 for the SN tracking service.

2.2.3 Operations Interface

The Operations Interface is the two-way interface between the customer ground facilities and the SN, as shown in Figure 2-1. This interface provides for the scheduling of SN support and the conduct of real-time SN operations. All aspects of this interface, with the exception of tracking measurements, are described in Section 10. Details regarding tracking measurements are provided in Section 9.

2.3 Elements of the SN

The SN is operated under the control of the GSFC MSP with the objective of providing tracking and data relay services to customer missions. The SN consists of a space segment and a ground segment. The space segment consists of a constellation of Tracking and Data Relay Satellites (TDRS). This TDRS constellation is divided as follows:

a. The basic TDRS program Flight 1 (F1) through Flight 6 (F6).

b. The TDRS replacement program Flight 7 (F7).

c. The TDRS follow-on program, TDRS H, I, J, which will be known as Flight 8 (F8) through Flight 10 (F10).

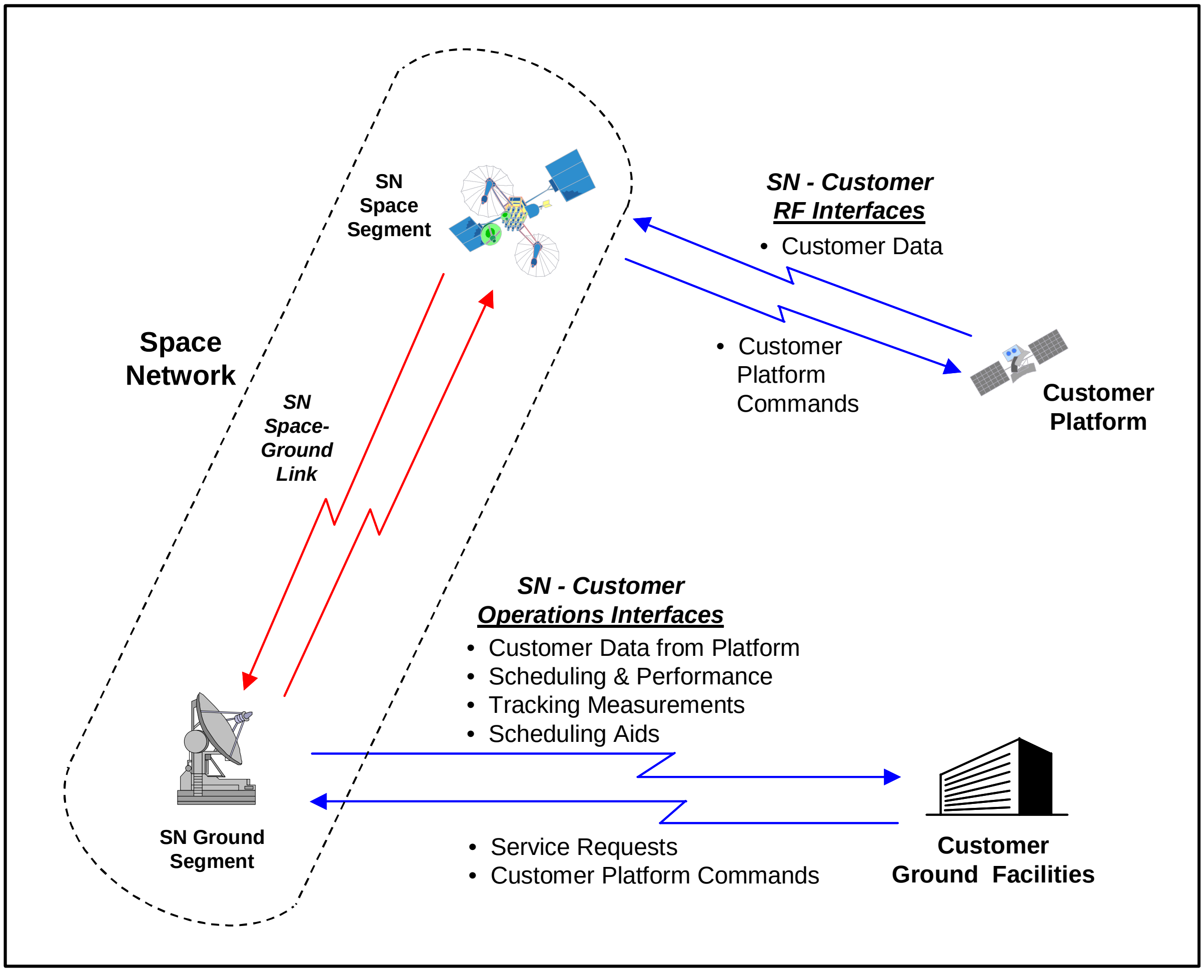


Figure 2-1. SN – Customer RF and Operations Interfaces

The ground segment consists of the White Sands Complex (WSC), the Bilateral Ranging Transponder System (BRTS), the Merritt Island Launch Area (MILA) TDRSS Relay, and the Data Services Management Center (DSMC). WSC, BRTS, and MILA Relay are dedicated to SN operations only, but the DSMC is shared with another NASA element, the Ground Network (GN).

The combination of the WSC and the TDRS constellation is also known as the Tracking and Data Relay Satellite System (TDRSS). The SN elements and interfaces are shown in Figure 2-2 and described in paragraphs 2.3.1 and 2.3.2 below.

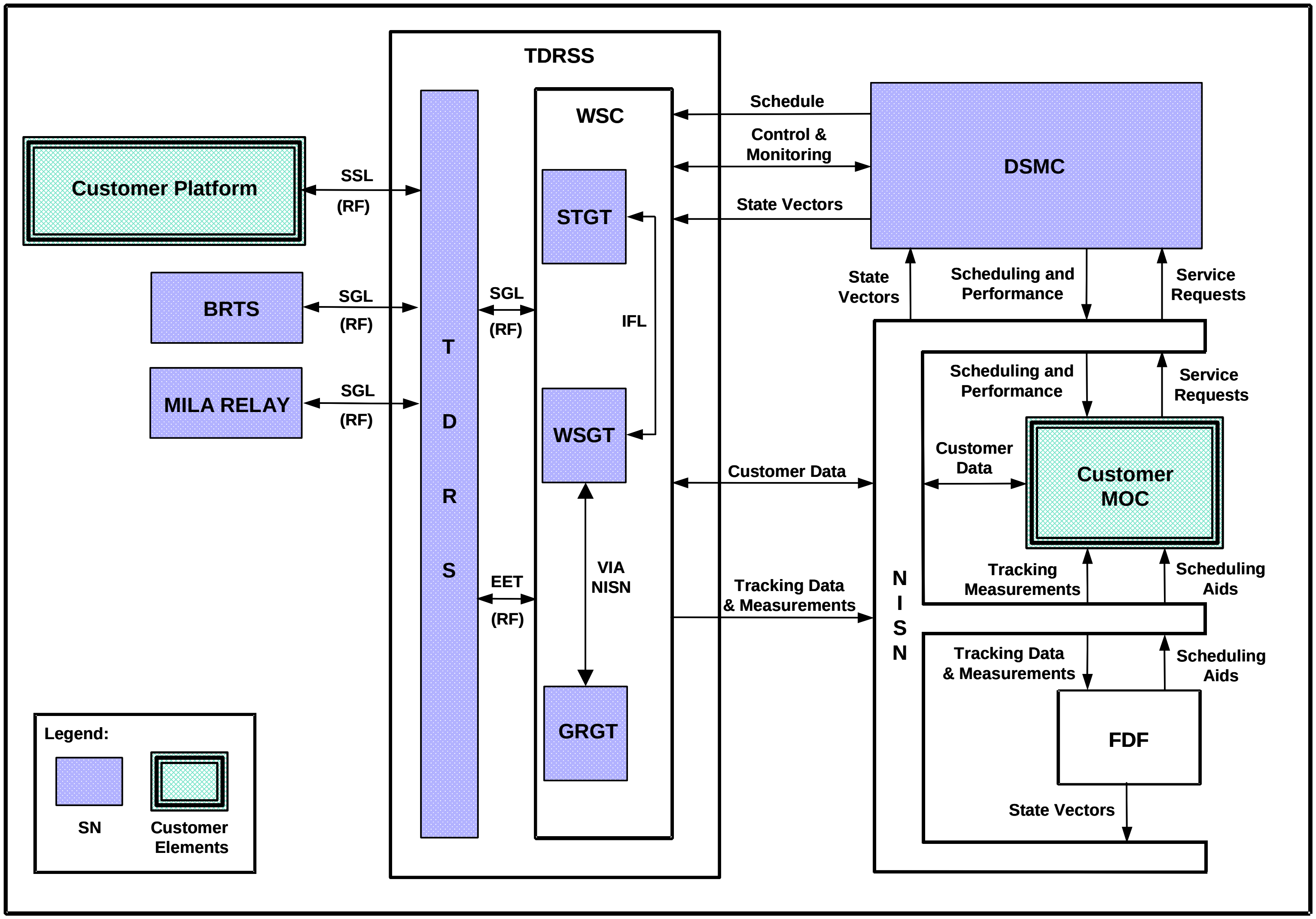


Figure 2-2. SN Elements and Interfaces

2.3.1 Space Segment

The space segment of the SN consists of up to six operational TDRSs in geosynchronous orbit at allocated longitudes for relaying forward and return service signals to and from customers for data transfer and tracking. An additional TDRS, F1, provides dedicated support to the National Science Foundation (NSF) through the use of the WSC Alternative Resource Terminal (WART) (refer to paragraph 2.4.h and Appendix M for further information). Additional spare TDRS may be in geosynchronous orbit. All first generation TDRSs (F1-F7) carry functionally identical payloads and all second generation TDRSs (F8-F10) carry functionally identical payloads. Figure 2-3 and Figure 2-4 identify the pertinent communications components and associated parameters of the first generation (F1-F7) and second generation (F8-F10) TDRSs, respectively.

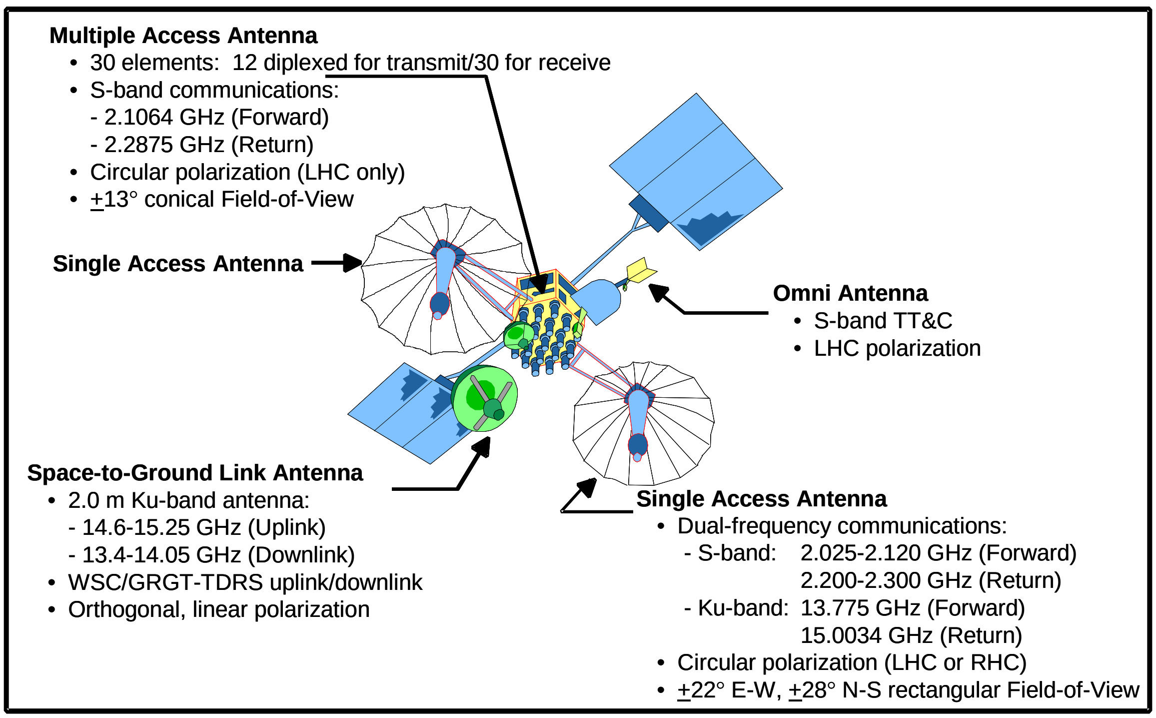


Figure 2-3. First Generation Tracking and Data Relay Satellite (F1-F7)

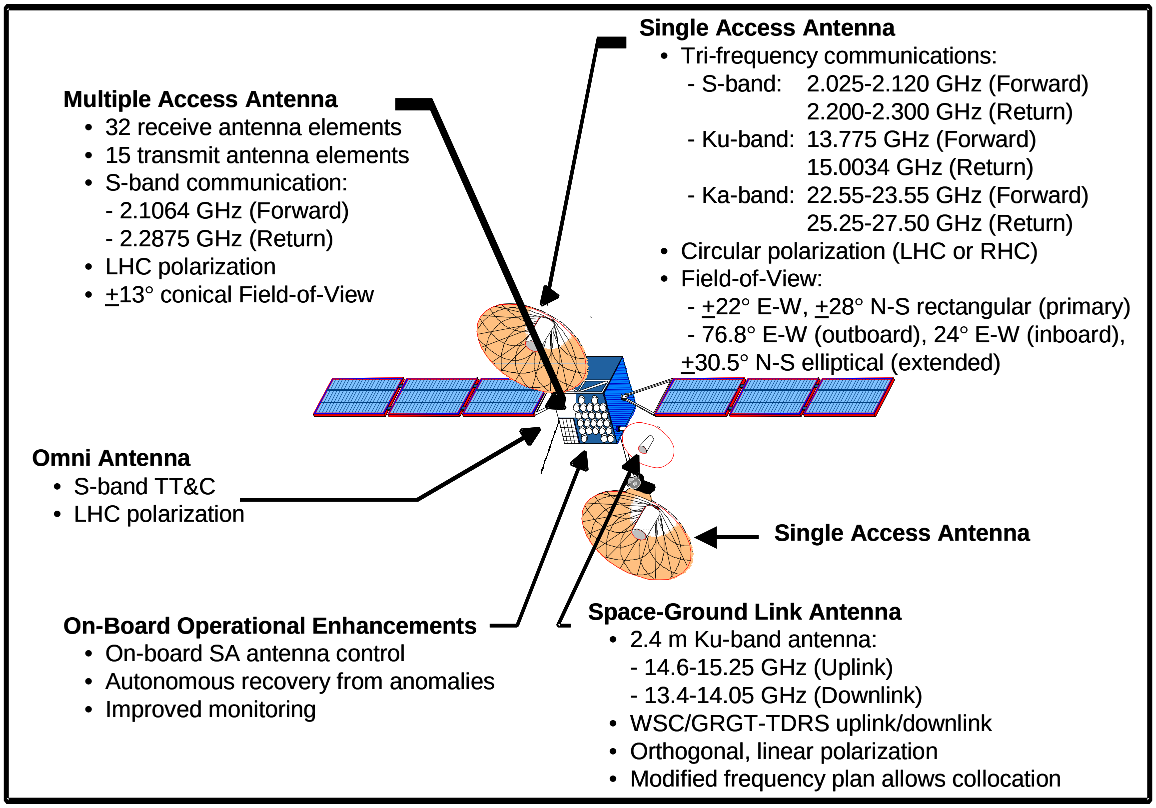


Figure 2-4. Second Generation Tracking and Data Relay Satellite (F8-F10 also known as H ,I, J)

2.3.1.1 Change of TDRS Location

The GSFC MSP may change the geosynchronous location of any TDRS to any other geosynchronous location assigned to NASA. SN customers should refer to the current location of the TDRS spacecraft on the What's New web page from the Space Network Online Information Center Homepage, which can be found at http://nmsp.gsfc.nasa.gov/tdrss/new.html#loc.

Table 2-1 provides examples of TDRS constellation plans. With TDRSs F8-F10, up to two spacecraft can be collocated in one longitudinal location. These two spacecraft may be either two second-generation TDRSs or one first-generation TDRS and one second-generation TDRS. This feature allows the use of two partially failed spacecraft to be collocated in order to conserve orbital slots.

2.3.1.2 TDRS Line-of-Sight Coverage

TDRS line-of-sight coverage depends on customer platform altitude and inclination as well as TDRS geosynchronous longitude, inclination, and field-of-view (FOV). Assuming TDRS located at 41°W, 174°W, and 85°E with a 0° inclination, 100 percent line-of-sight global coverage can be provided for:

Table 2-1. Examples of TDRS Constellation Plans

Example Constellation Plan (note 1)	Geosynchronous Longitudes of First Generation Satellites (TDRSs F1-F7)	Geosynchronous Longitudes of Second Generation Satellites (TDRSs F8-F10) (note 2)
1. First Generation TDRSs only	41°W (F4) 47°W (F6) 49°W (F1) (note 3) 171°W (F7) 174°W (F5) 85°E (F3)	
2. First Generation TDRSs and 1 Second Generation TDRS	41°W (F4) 46°W (F6) 49°W (F1) (note 3) 171°W (F7: inactive) 174°W (F5) 85°E (F3)	171°W (F8)
3. First Generation TDRSs and 3 Second Generation TDRSs	41°W 49°W (note 3) 174°W 85°E	46°W 171°W 79°W (stored spare)

Notes:

1. For exact TDRS orbital locations, please refer to the current location of the TDRS spacecraft on the What's New web page from the Space Network Online Information Center Homepage, which can be found at http://nmsp.gsfc.nasa.gov/tdrss/new.html#loc. Additionally, the detailed TDRS spacecraft orbit (including inclination) can be found by referring to the element reports under the view mission products on the Flight Dynamics Facility (FDF) Product Center web page, which can be found at http://mmfd.gsfc.nasa.gov/prod_center/pc_frame_page.htm.
2. The TDRS F8-F10 (H, I, J) spacecraft have the capability of supporting collocation on-orbit. When collocated, TDRS telecommunications services are provided from: 1) 2 TDRS F8-F10 in the same assigned orbital location (slot) with nodal crossings within 0.1 degrees of the assigned longitude, or 2) 1 TDRS F8-F10 and 1 TDRS F1-F7 in the same assigned orbital location (slot) with nodal crossings within 0.1 degrees of the assigned longitude. All services scheduled for a customer in a single event must be provided by a single TDRS; therefore, collocation may preclude scheduling of certain combinations of services.
3. Not available for normal user scheduling – used for WART operation.

a. Customer altitudes between 73 km and 1000 km for the Multiple Access (MA) and Ku- and Ka-band Single Access (SA) low earth orbit (LEO) FOV (LEOFOV) limits of ±10.5° (conical) (refer to Figure 2-5 for an example average percent coverage and Sections 5, 7, and 8 for a description of MA, KuSA, and KaSA LEOFOV services)

b. Customer altitudes between approximately 73 km and 3000 km for the MA Primary FOV (PFOV) limits of ±13° (conical) (refer to Figure 2-6 for an example average percent coverage and Section 5 for a description of MA service).

c. Customer altitudes between approximately 73 km and 9000 km for the SA PFOV limits of ±22°E-W and ±28°N-S (rectangular) (refer to Figure 2-7 for an example average percent coverage and Sections 6 through 8 for a description of PFOV SA services).

The TDRSs F8-F10 SA antennas have an Extended Elliptical FOV (EEFOV) of 76.8°E-W (outboard), 24°E-W (inboard), and ±30.5°N-S, which will allow for coverage to customers in geosynchronous orbit. Figure 2-8 depicts the average percent coverage assuming the SA EEFOV for TDRSs F8-F10 located at 41°W and 174°W with 0° inclination and the SA PFOV for TDRSs F1-F7 located at 85°E with a 0° inclination. The average percent coverage figures consider only geometric line-of-sight coverage and do not consider other coverage constraints such as flux density restrictions, periods of RFI, customer platform constraints, and service limitations, including sun and weather interference, scheduling availability, or mutual interference. In this document, the percent coverage is provided for example and more detailed coverage analysis (refer to paragraph 3.5.2) is available for a customer's specific conditions.

NOTE

The TDRSs are geosynchronous satellites, which have the same orbit period as a geostationary satellite, but their orbit may be elliptical and inclined. A geosynchronous satellite in an inclined circular orbit moves in a figure-8 pattern as viewed from earth. The TDRSs F1-F7 and F8-F10 maintain nodal crossings to within ±0.1° of the assigned longitude. In general, the SN does not require stringent north-south station keeping to maintain TDRSS services. The detailed TDRS spacecraft orbit (including inclination) can be found by referring to the element reports under the view mission products on the Flight Dynamics Facility (FDF) Product Center web page, which can be found at http://mmfd.gsfc.nasa.gov/prod_center/pc_frame_page.htm.

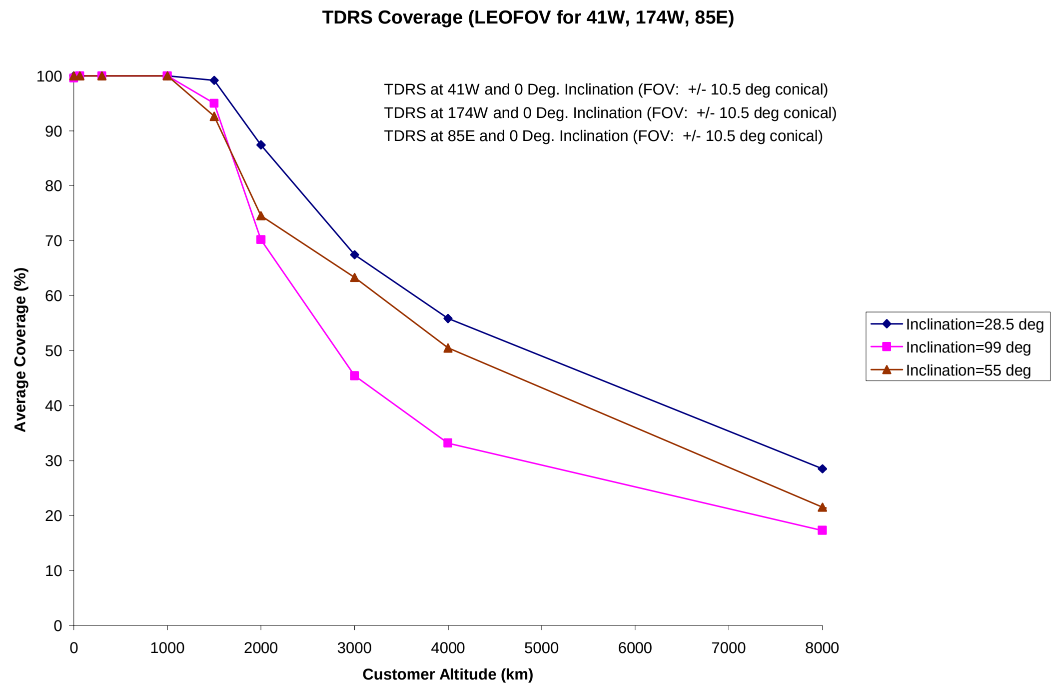


Figure 2-5. <u>Example</u> Average Line-of-Sight Coverage for LEOFOV

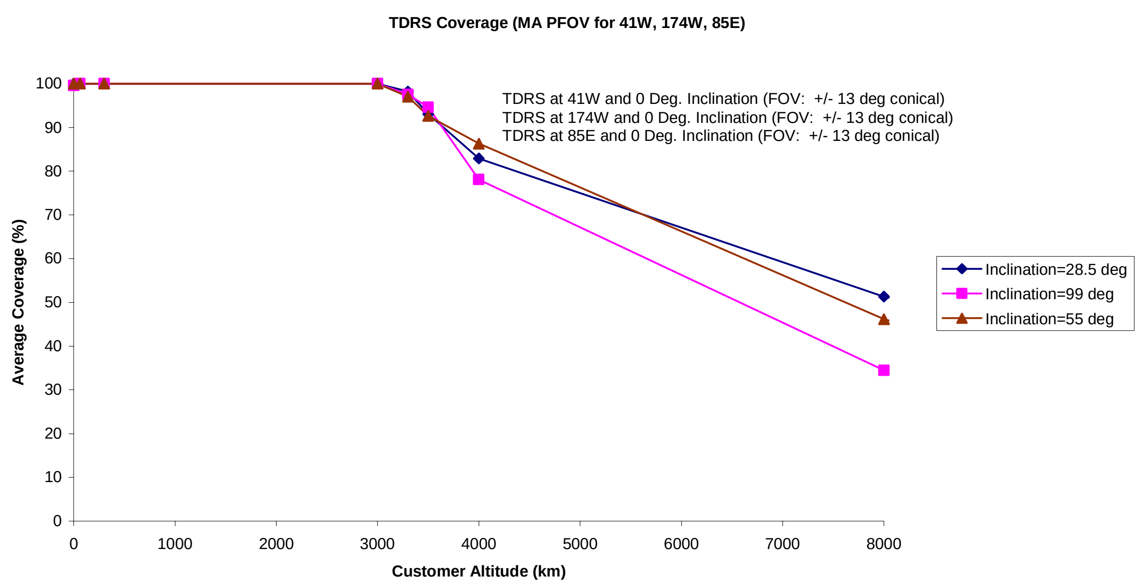


Figure 2-6. <u>Example</u> Average Line-of-Sight Coverage for MA PFOV

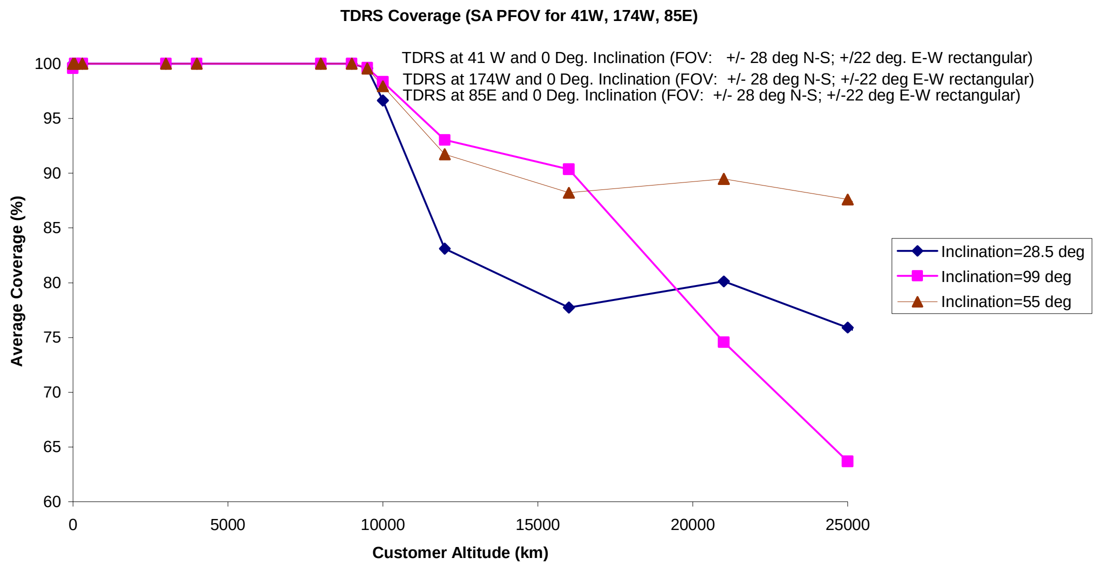


*Figure 2-7. **Example** Average Line-of-Sight Coverage for SA PFOV*

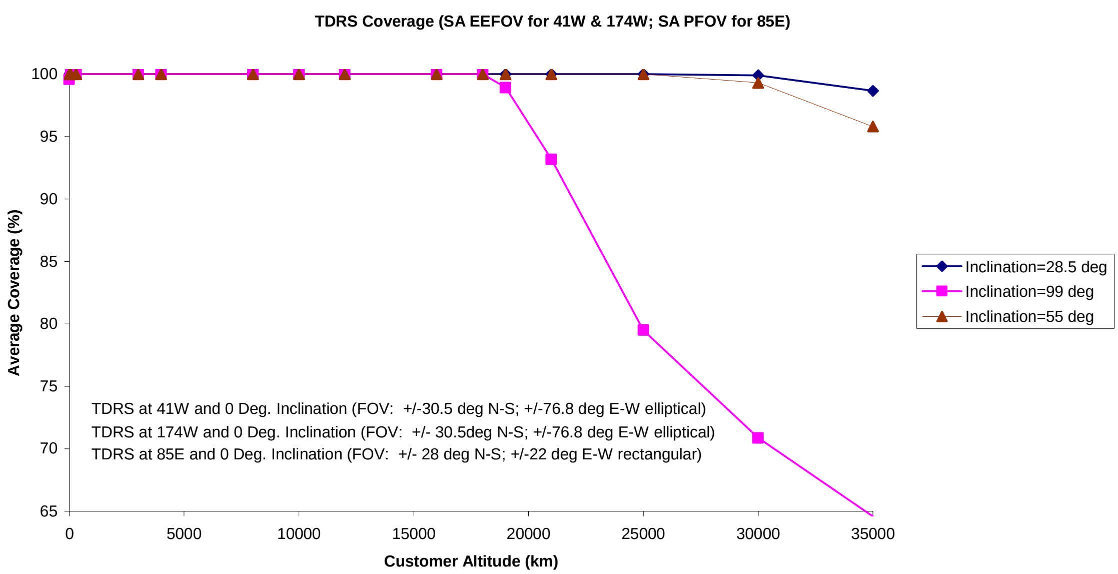


*Figure 2-8. **Example** Average Line-of-Sight Coverage for SA EEFOV*

2.3.2 Ground Segment

2.3.2.1 Dedicated Ground Elements

The majority of SN ground segment elements are dedicated to SN operations only. The SN dedicated ground elements are as follows:

a. White Sands Complex (WSC). The WSC provides the communications equipment necessary for transmitting and receiving data and tracking information relayed via each TDRS. The WSC consists of three ground terminals: the White Sands Ground Terminal (WSGT), the Second TDRSS Ground Terminal (STGT), and the Guam Remote Ground Terminal (GRGT). The WSGT and STGT are independently operated ground terminals, each containing a number of autonomous Space-Ground Link Terminals (SGLTs). WSGT contains two SGLTs and STGT contains three SGLTs. GRGT is a SGLT that is extended from and operated remotely via the WSGT. Each SGLT contains the hardware and software required to provide customer telecommunications and tracking services and tracking, telemetry, and command (TT&C) functions for the assigned TDRS. SGLT operations are controlled and monitored through the TDRSS Operations Control Center (TOCC). A data link, known as the Interfacility Link (IFL), exists between the WSGT and the STGT for the exchange of customer data and tracking information. The interface between WSGT and GRGT is accomplished by a commercial common carrier provided by the NASA Integrated Services Network (NISN). Equipment is available at all three sites to provide the customers with end-to-end system testing capabilities. Additional WSC functions include both data handling (refer to paragraph 3.6) and unique support for Shuttle.

b. Merritt Island Launch Area (MILA) TDRSS Relay. The MILA Relay provides RF signal routing between the TDRS and payloads or platforms under test prior to launch in support of Kennedy Space Center (KSC), Johnson Space Center (JSC), or customer MOCs. MILA also provides a relay between payloads and NISN facilities for the MOCs during the prelaunch period, when needed.

c. Bilateration Ranging Transponder System (BRTS). The BRTS consists of unmanned and totally automated transponders and provides, in conjunction with the TDRSS and the Flight Dynamics Facility (FDF), metric tracking data for the accurate determination of the ephemerides for each in-orbit TDRS. The BRTS transponders are presently located at the WSC, central Australia, Ascension Island, and American Samoa.

2.3.2.2 Data Services Management Center (DSMC)

An additional element of the SN ground segment is the DSMC (formerly known as the Network Control Center (NCC) – see the note below). Unlike WSC, MILA Relay, and BRTS, the DSMC is not dedicated to SN support only, in that is also provides support to the NASA GN as well. Collocated with WSC, the DSMC is the operations control facility for the SN. It schedules all SN elements and supporting elements and provides interfaces for planning, acquisition, control, and status of the SN. The DSMC is the point-of-contact between customers and the SN for scheduling and real-time performance. A customer may obtain SN support by submitting specific schedule requests to or establishing generic requirements with the DSMC. The DSMC translates customers' requirements into specific events. Additionally, the DSMC notifies affected customers of scheduled system outages so that MOCs can properly plan mission activities. Upon MOC request, the DSMC provides operational performance information (such as data presence monitoring indicators and data quality monitoring data) on scheduled services during actual support to determine if conditions exist that will affect data quality. For further information on the MOC/DSMC interface, please refer to Section 10 of this document.

NOTE

The SN is in the midst of a network architecture change that will result in all functions and interfaces previously supported by the NCC in Greenbelt, MD, being moved to the DSMC in White Sands, NM. The transition of these functions and interfaces to the DSMC will be completed in 2002. The use of the term "NCC" is currently widespread throughout SN and customer documentation. To help manage terminology and documentation during and after the transition, the term "NCC" will continue to be used as a valid term. Over time, the term "NCC" will be phased out during the normal course of document changes. This document has been updated to reflect a transition to the term "DSMC".

NOTE

The DSMC issues Network Advisory Messages (NAMs) to provide up-to-date information on network conditions and constraints. These messages are accessible via the DSMC active NAM web site at http://128.183.140.27/nam/wnserch.htm.

2.4 Supporting Elements Outside the SN

NASA elements not part of the SN that support SN operations are as follows:

a. NASA Integrated Services Network (NISN). NISN is a global system of communications transmission, switching and terminal facilities that provide NASA with wide area network communications services. NISN services which support the SN include realtime and mission critical Internet Protocol (IP) routed data as well as high rate data and video services connecting the WSC to NASA Centers. Inter-center mission voice communications services are also provided for management of the network and support of the customer's mission. For further information on NISN, refer to Appendix I.

b. Flight Dynamics Facility (FDF). Located at GSFC, the FDF provides support to the SN and NASA approved customer platform missions for orbit determination, acquisition data generation, attitude determination, and orbit and attitude maneuver support. The FDF also controls and schedules the BRTS for TDRS tracking and monitors the BRTS status.

c. RF Simulation Operations Center (RF SOC)/Simulation Operations Center (SOC). The RF SOC and SOC, located at GSFC, provide facilities for conducting customer flight project mission simulations for SN customers. It can monitor SN performance during these mission simulations, simulate a mission-unique customer platform, verify SN/customer MOC interfaces, and simulate a customer MOC in support of fault isolation.

d. Compatibility Test Van (CTV)/Compatibility Test Laboratory (CTL). Home-based at GSFC, two CTVs provide the means to test customer platforms at remote locations for RF compatibility with the SN, which may include an end-to-end test after compatibility testing is completed. Each CTV can provide cabled RF interfaces to a customer platform for local RF compatibility testing. The CTV also has a rooftop antenna for TDRSS relay performance tests. Similar in capability to the CTV, the GSFC-based CTL can provide cable RF interfaces to a customer platform for local RF testing and a rooftop antenna for SN performance tests. In this case, the customer brings the platform RF components to the GSFC CTL and these components are set up in an RF-shielded screen room for testing.

e. Ground Network (GN). The GN consists of NASA ground stations located in: Spitsbergen, Norway; Merritt Island (MIL) and Ponce de Leon (PDL), Florida; Poker Flat Research Range and the Alaska Synthetic Aperture Radar (SAR) Facility (ASF) in Fairbanks, Alaska; McMurdo, Antarctica; and Wallops Island, Virginia. Most of these stations provide orbital communications support for orbiting customer platforms. Additionally, some of these stations provide prelaunch, launch, and landing communications support for launch vehicles and the Space Transportation System (STS). The GN and SN combined comprise the Spaceflight Tracking and Data Network (STDN).

f. Deep Space Network (DSN). Managed by the Jet Propulsion Laboratory (JPL), Pasadena, CA, the DSN is comprised of ground tracking stations at Canberra, Australia; Goldstone, California; and Madrid, Spain. The DSN stations are used to support a standard mission set and provide emergency support in the event of customer contingency or degraded STDN support. The DSN also provides telecommunications and tracking support during TDRS launch and the subsequent transfer operations.

g. McMurdo TDRSS Relay System (MTRS). The MTRS consists of two TDRS relay ground systems which are within the NSF McMurdo facilities in the Antarctic. The MTRS can be used to relay up to 300 Mbps through TDRS to WSC. Presently, these systems are evolving into a future operational status; they are currently being used for special purpose data relay. For further information on the MTRS, please refer to Appendix L.

h. South Pole TDRSS Relay (SPTR) and WSC Alternative Resource Terminal (WART). The SPTR, located at the Amundsen-Scott South Pole Station, Antarctica, provides high data rate communications links with the South Pole on a daily basis via the TDRSS to support interactive connectivity for the Antarctic scientific experimenter community. The SPTR is a dedicated service specifically for relay of data from the South Pole and utilizes a partial SGLT at WSC, which is known as WART. For further information of the SPTR/WART, please refer to Appendix M.

Section 3. Services Available to Customers

3.1 General

The SN along with its supporting elements can provide various services to customers including: Telecommunications, Tracking, Testing, Analysis, and Data Distribution/ Processing Services.

3.2 Telecommunications Services

Several types of telecommunications service are simultaneously available to customers. The type of telecommunications service selected is determined by the data rate required, duration of service period, and customer platform telecommunications system design. The two primary telecommunications services are termed Multiple Access (MA) and Single Access (SA). The SA services are available at S-band, Ku-band, and Ka-band (F8-F10 only) frequencies.

The SN can provide any of the following services:

a. A forward service, defined as the communication path that generally originates at the customer control center and is routed through WSC to the TDRS to the customer platform.

b. A return service, defined as the communication path that generally originates at the customer platform and is routed through the TDRS to WSC back to the customer control center and/or data acquisition location.

c. Both forward and return services simultaneously.

The forward service is typically utilized for customer platform commanding and may include a separate ranging channel for use in tracking services. Forward service data rates are variable depending on the forward service type, which are S-band Multiple Access Forward (MAF) through TDRS F1-F7, S-band Multiple Access Forward (SMAF) through TDRS F8-F10, S-band Single Access Forward (SSAF), Ku-band Single Access Forward (KuSAF), and Ka-band Single Access Forward (KaSAF) through TDRS F8-F10. Table 3-1 provides an overview of the TDRSS forward service characteristics.

The return service is typically utilized for the return of science data and customer platform status information. The return service consists of up to two channels, which may include a pseudorandom noise (PN) code for use in ranging services and to reduce power flux density. Similar to the forward service, return service data rates are variable depending on the return service type, which are S-band Multiple Access Return (MAR) through TDRS F1-F7, S-band Multiple Access Return (SMAR) through TDRS F8-F10, S-band Single Access Return (SSAR), Ku-band Single Access Return (KuSAR), and Ka-band Single Access Return (KaSAR) through TDRS F8-F10. Return services are divided into two major groups, Data Group 1 (DG1) and Data Group 2 (DG2). DG1 services utilize spread spectrum modulation while DG2 services are non-spread.

Table 3-1. TDRSS Forward Service Characteristics

	MA (TDRS F1-F7 / TDRS F8-F10)	SSA	KuSA	KaSA (TDRS F8-F10)
Customer service links/satellite (note 2)	1	2	2	2/TDRS up to 8/WSC
Space-to-Space Freq. Bands	2106.4 MHz	2025.8-2117.9 MHz (note 6)	13.775 GHz	22.55-23.55 GHz (note 6)
Space-Space Polarization	LHCP only	LHCP and RHCP (selectable) (note 9)	LHCP and RHCP (selectable) (note 9)	LHCP and RHCP (selectable) (note 9)
RF Channel BW (3 dB, minimum)	6 MHz	20 MHz	50 MHz	50 MHz
Max Data Rate	300 kbps	7 Mbps	25 Mbps (note 5)	25 Mbps (note 5)
Modulation Scheme (notes 1 and 4)	QPSK; data rates ≤300 kbps	QPSK for data rates ≤ 300 kbps BPSK for data rates > 300 kbps PCM/PM for data rates ≤ 1 Mbps PCM/PSK/PM for data rate ≤ 8 kbps	QPSK for data rates ≤300 kbps BPSK for data rates > 300 kbps	QPSK for data rates ≤300 kbps BPSK for data rates > 300 kbps
Field of View (max.) (note 3)	• Primary (PFOV): ± 13° conical • LEOFOV: ± 10.5° conical	• PFOV: (rectangular) ± 22° east-west ± 28° north-south • Extended Elliptical (EEFOV) (F8-F10 only): 76.8° east-west (outboard) 24° east-west (inboard) ± 30.5° north-south	• PFOV: (rectangular) ± 22° east-west ± 28° north-south • LEOFOV: ± 10.5° conical • EEFOV (F8-F10 only): 76.8° east-west (outboard) 24° east-west (inboard) ± 30.5° north-south	• PFOV: (rectangular) ± 22° east-west ± 28° north-south • LEOFOV: ± 10.5° conical
Minimum Forward Link EIRP (note 3)	• PFOV: F1-F7: 34 dBW F8-F10: 40 dBW • LEOFOV: F1-F7: 34 dBW F8-F10: 42 dBW	• PFOV (F1-F10) and EEFOV (F8-F10 only): Normal/high mode: 43.6 dBW/48.5 dBW (note 7)	• PFOV (F1-F10) and EEFOV (F8-F10 only): Normal/high autotrack mode: 46.5 dBW/48.5 dBW (notes 7,8,10) Normal/high program track mode: 40.5 dBW/42.5 dBW (note 7) • LEOFOV: Normal/high autotrack mode: 46.5 dBW/48.5 dBW (notes 7,10) Normal/high program track mode: 44.0 dBW/46 dBW (note 7)	• PFOV: Autotrack: 63.0 dBW (note 10) Program track: 56.2 dBW • LEOFOV: Autotrack: 63.0 dBW (note 10) Program track: 59.5 dBW

Table 3-1. TDRSS Forward Service Characteristics (cont'd)

NOTES:

1. TDRSS spacecraft are capable of bent-pipe operation to support user defined (non-TDRSS) signal formats. Non-TDRSS signal formats may require the addition of ground terminal modulation/demodulation equipment. Precise performance will have to be handled on a case-by-case basis.
2. TDRS F8-F10 Ku and Ka-band forward services cannot be supported simultaneously through the same SA antenna. GRGT is not currently planned to support a TDRS F8-F10 spacecraft.
3. For a thorough description of the service performance and additional constraints for the various FOVs, please see Sections 5 through 8 for MA, SSA, KuSA, and KaSA services.
4. For data rates $\leq$300 kbps, the I channel contains the command data and is modulo-2 added to a 3 Mcps PN code and the Q channel is a 3 Mcps PN code.
5. Current WSC data interface supports up to 7 Mbps; however, upgrades to support up to 25 Mbps are planned.
6. For specific center frequency assignments, please coordinate with the GSFC MSP and your associated spectrum management office.
7. Use of the high power mode is restricted, and must be coordinated with the GSFC MSP prior to use.
8. The KuSA forward autotrack performance for EEFOV is a goal and will be supported on a best-effort basis.
9. The forward and return polarization for each band must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.
10. The autotrack service can experience longer outages due to RFI as the SA antenna will track the interfering signal rather than the desired signal. Additionally, the autotrack system can occasionally "wander" during signal fade or no RF conditions, which can cause a delay in acquisition after the signal is restored to its proper level.

Table 3-2 provides an overview of the TDRSS return service characteristics. Table 3-3 summarizes the differences between the SN data group and modes used for return service operations.

Each TDRS providing customer services is assigned a WSC SGLT. The assigned SGLT performs both TT&C functions and customer telecommunications and tracking functions in support of TDRS operations. However, not all SGLTs possess the same telecommunications service capabilities. Figure 3-1 provides an overview of customer services available through each WSC SGLT.

3.2.1 MA Service Overview

MA (also referred to as S-band Multiple Access (SMA) for TDRS F8-F10) forward and return services operate at fixed S-band frequencies (nominally 2106.4 MHz forward and 2287.5 MHz return) and polarization (Left Hand Circular). Forward service operations are time-shared amongst TDRS customers where one customer is supported per TDRS at a time. The TDRS F1-F7 MA return service is provided by an on-board 30 element phased array antenna in conjunction with beamforming equipment located in the ground station. The TDRS F8-F10 SMA return service is provided by an array of 32 elements in conjunction with TDRS on-board beamforming. The arrays on both generations of TDRS allow for spatial discrimination due to the phase differential of the customer signal received at each spaced antenna element on the TDRS. The standard network MA services through TDRS F1-F7 and F8-F10 are one forward and five return services per TDRS. The number of TDRS F1-F7 MA return services supported by a WSC SGLT is limited by the quantity of ground MA equipment and the level of self interference among customers. The SN is currently developing a Demand Access System (DAS) that will allow expansion of the TDRSS F1-F7 MAR DG1 mode 2 services well beyond the standard number of return services per TDRS/SGLT. For further information on DAS, refer to Appendix H.

NOTE

> Unless denoted by the TDRS fleet, the term MA is used throughout this document to denote MA services through TDRS F1-F7 and TDRS F8-F10. If the term SMA is used, these capabilities are specific to TDRS F8-F10.

3.2.2 SA Service Overview

SA services available through each TDRS SA antenna are: SSAF, SSAR, KuSAF, KuSAR, KaSAF (F8-F10 only), and KaSAR (F8-F10 only). Each TDRS SA antenna has one polarizer (either Left Hand Circular or Right Hand Circular) for each frequency band (S, Ku, or Ka). The forward and return polarization for each band must be the same in order to obtain simultaneous forward and return services through the same SA antenna. The SN can simultaneously support S-band and K-band (either Ku-band or Ka-band (F8-F10 only)) forward and/or return services through one SA antenna to the same ephemeris. TDRS F8-F10 cannot simultaneously support Ku-band and Ka-band services through one SA antenna.

Table 3-2. TDRSS Return Service Characteristics

	MA (note 6) (TDRS F1-F7 / TDRS F8-F10)	SSA	KuSA	KaSA (TDRS F8-F10)
Customer service links/satellite (notes 2 and 5)	5/TDRS up to 20/WSC 2/TDRS through GRGT	2	2	2/TDRS up to 8/WSC
Space-to-Space Freq. Bands	2287.5 MHz	2200-2300 MHz (note 7)	15.0034 GHz	25.25-27.5 GHz (note 7)
Space-Space Polarization	LHCP only	LHCP and RHCP (selectable) (note 10)	LHCP and RHCP (selectable) (note 10)	LHCP and RHCP (selectable) (note 10)
RF Channel BW (3 dB, minimum)	6 MHz	10 MHz	225 MHz	225 or 650 MHz (note 4)
Max Data Rate	300 kbps (F1-F7) / 3 Mbps (F8-F10) (rate ½ coded)	6 Mbps (rate ½ coded)	300 Mbps (uncoded) (note 12)	300 Mbps (uncoded) (note 4)
Return FEC Scheme	Rate 1/2 convol. (F1-F7) / Rate 1/2 or 1/3 convol. (F8-F10)	Rate 1/2 or 1/3 convol.	Rate 1/2 convol. or uncoded	Rate 1/2 convol. or uncoded
Return Data Group and Mode (note 1)	DG1 modes 1 and 2 (F1-F7) / DG1 and DG2 (F8-F10)	DG1 and DG2	DG1 and DG2	DG2
Field of View (max.) (note 3)	• PFOV: ± 13° conical • LEOFOV: ± 10.5° conical	• PFOV: (rectangular) ± 22° east-west ± 28° north-south • EEFOV (F8-F10 only): 76.8° east-west (outboard) 24° east-west (inboard) ± 30.5° north-south	• PFOV: (rectangular) ± 22° east-west ± 28° north-south • LEOFOV: ± 10.5° conical • EEFOV (F8-F10 only): 76.8° east-west (outboard) 24° east-west (inboard) ± 30.5° north-south	• PFOV: (rectangular) ± 22° east-west ± 28° north-south • LEOFOV: ± 10.5° conical • EEFOV: 76.8° east-west (outboard) 24° east-west (inboard) ± 30.5° north-south
TDRS G/T (minimum) (note 3)	Formed Beam: • PFOV: F1-F7: 2.2 dB/K F8 (cold)-F10: 3.2 dB/K F8 (hot): -0.2 dB/K (note 9) • LEOFOV: F1-F7: 3.1 dB/K F8 (cold), F9-F10: 4.5 dB/K F8 (hot): 1.2 dB/K (note 9)	• PFOV: 9.5 dB/K • EEFOV (F8-F10 only): 9.5 dB/K	• PFOV (F1-F10) and EEFOV (F8-F10 only): Autotrack: 24.4 dB/K (notes 8, 11) Program track: 18.4 dB/K • LEOFOV: Autotrack: 24.4 dB/K (note 11) Program Track: 21.9 dB/K	• PFOV and EEFOV: Autotrack: 26.5 dB (notes 8,11) Program track: 19.1 dB/K (PFOV only) • LEOFOV: Autotrack: 26.5 dB (note 11) Program Track: 23.0 dB/K

Table 3-2. TDRSS Return Service Characteristics (cont'd)

NOTES:

1. TDRSS spacecraft is capable of bent-pipe operation to support user defined (non-TDRSS) signal formats. Non-TDRSS signal formats may require the addition of ground terminal modulation/demodulation equipment. Precise performance will have to be handled on a case-by-case basis.
2. TDRS HIJ Ku and Ka-band return services cannot be supported simultaneously through the same SA antenna.
3. For a thorough description of the service performance and additional constraints for the various FOVs and antenna tracking modes, please see Sections 5 through 8 for MA, SSA, KuSA, and KaSA services. The TDRS G/T is a component of the P_{rec} equations provided in Sections 5 through 8. The required P_{rec} values should be used as a guide for determining SN performance.
4. Higher return link data rates may be possible when the ground terminal is modified to receive 650 MHz bandwidth. A Ka-band IF service capable of supporting the 650 MHz bandwidth is currently under development. Please contact the GSFC MSP for further information.
5. Guam Remote Ground Terminal (GRGT) is not currently planned to support a TDRS F8-F10 spacecraft.
6. The Space Network is currently developing a Demand Access System (DAS) that would allow expansion of the TDRSS F1-F7 MAR DG1 mode 2 services well beyond the standard number of return services per TDRS/SGLT. For further information on DAS, refer to Appendix H.
7. For specific center frequency assignments, please coordinate with the GSFC MSP and your associated spectrum management office.
8. The KuSA and KaSA return autotrack performance for EEFOV is a goal and will be supported on a best-effort basis.
9. The F8 spacecraft has some SMA return G/T performance variations due to an MA element array and sunshield proximity problem. The G/T varies based upon the normal daily TDRS diurnal cycle. The hot periods can be predicted and will occur at regular intervals with a total hot period of less than 12 hours/day. Customers attempting to schedule around hot periods, should reference the Flight Dynamics Facility Products Center web at http://mmfd.gsfc.nasa.gov/prod_center/pc_frame_page.htm for further information on the daily TDRS-8 diurnal cycle.
10. The forward and return polarization for each band must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.
11. The autotrack service can experience longer outages due to RFI as the SA antenna will track the interfering signal rather than the desired signal. Additionally, the autotrack system can occasionally "wander" during signal fade or no RF conditions, which can cause a delay in acquisition after the signal is restored to its proper level.
12. GRGT support of KuSA return data rates in excess of 150 Mbps should be discussed with GSFC MSP.

Table 3-3. Return Link Data Group and Mode Description

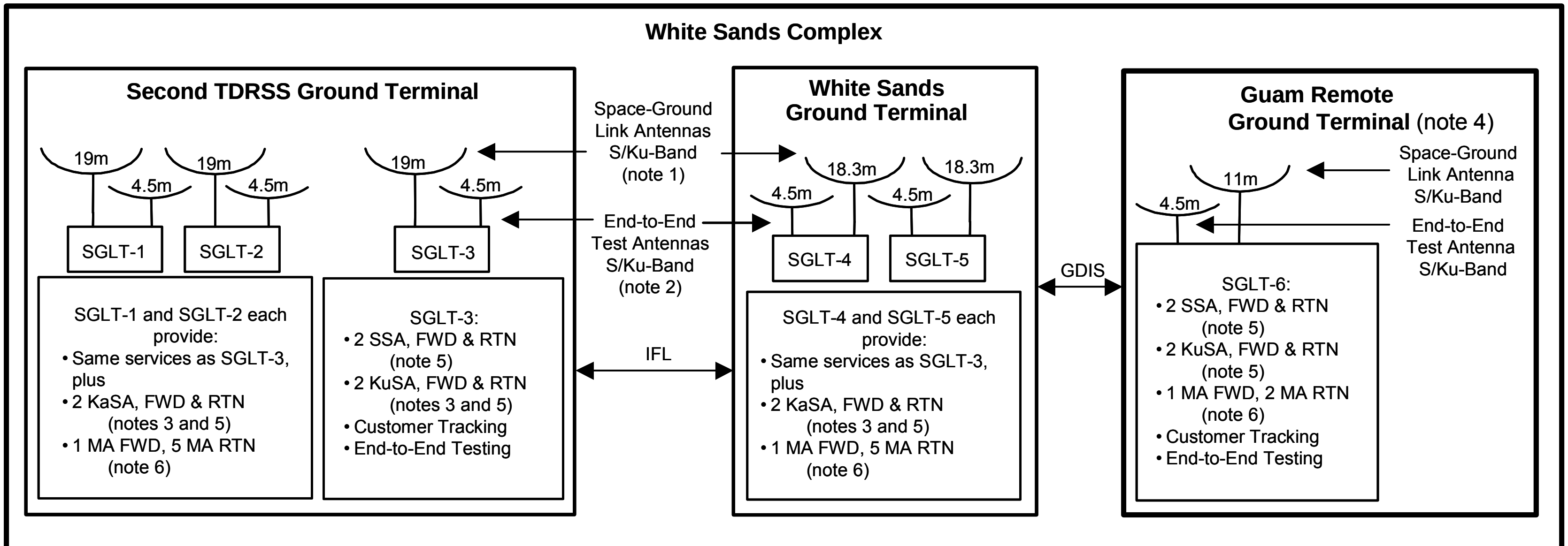
Data Group and Mode (note 4)	Doppler Measurements		Range and Time Transfer Measure-ments (note 2)	3 Mcps PN code added asynchronously to channel symbol stream	Baud Rate Transmission
	1-way	2-way (note 1)			
DG1 mode 1		✓	✓	I and Q	I: Low rate ($\le$ 300 ksps MA, SSA, KuSA) Q: Low rate ($\le$ 300 ksps MA, SSA, KuSA)
DG1 mode 2	✓			I and Q	I: Low rate ($\le$ 300 ksps MA, SSA, KuSA) Q: Low rate ($\le$ 300 ksps MA, SSA, KuSA)
DG1 mode 3		✓	✓	I only	I: Low rate ($\le$ 300 ksps SMA F8-F10, SSA, KuSA) Q: up to High rate ($\le$ 3 Msps SMA F8-F10; $\le$ 6 Msps SSA; $\le$ 300 Msps KuSA)
DG2 coherent		✓		None	I: up to High rate ($\le$ 3 Msps SMA F8-F10; $\le$ 6 Msps SSA; $\le$ 300 Msps Ku/KaSA) Q: up to High rate ($\le$ 3 Msps SMA F8-F10; $\le$ 6 Msps SSA; $\le$ 300 Msps Ku/KaSA (note 3)
DG2 noncoherent	✓			None	

NOTES:

1. Requires that the customer transponder coherently turns around the received forward service carrier.
2. Requires that the customer transponder coherently turns around the PN code epoch received in the forward service range channel.
3. TDRS F8-F10 support KaSA forward and return DG2 noncoherent services. Tracking services are not available through KaSA service. Higher KaSA return link symbol rates may be possible when the ground terminal is modified to receive 650 MHz bandwidth.
4. Return channel time delay (RCTD) is available for all return link data groups and modes for 4800-bit block customers.

3.2.2.1 Virtual Customer Platforms

It is normally impossible for two customer platforms to use the same SA antenna at the same time. However if a single customer MOC operates two platforms that dock while on-orbit or that otherwise maintain a close physical relationship while on-orbit, it may be possible for both of these platforms to use the same SA antenna at the same time. This can be done by defining a virtual customer platform with the S-band characteristics of one of the real platforms and the K-band (Ku or Ka) characteristics of the other. Data for this virtual platform can be entered into the DSMC database in the same manner as is data for any other platform. After the database is established, the MOC's interaction with the SN for the virtual customer platform is the same as for a real platform and SN operations proceed normally. This approach allows both of these platforms to have SA support on one of a TDRS's SA antennas while leaving the other SA antenna available for other users. Use of this approach is encouraged whenever feasible.



Notes:

1. The WSGT SGL antennas support Ku-band operations only.
2. Currently, there is no end-to-end test services at Ka-band.
3. Each TDRS F8-F10 supports either KuSA or KaSA services through each SA at a time.
4. There is no requirement to support TDRS F8-F10 through GRGT.
5. The SN can simultaneously support S-band and K-band (either Ku or Ka for F8-F10) forward and/or return services through 1 SA antenna to same ephemeris.
6. The SN is currently developing a Demand Access System (DAS) that would allow expansion of the TDRSS F1-F7 MAR DG1 mode 2 services well beyond the standard number of return services per TDRS/SGLT.

Figure 3-1. Telecommunications Services for each SGLT

For the virtual customer platform concept to be viable, the differences between the vectors for the two real platforms should be small. Either the customer MOC or the FDF must provide the DSMC with improved interrange vectors (IIRVs) for the virtual platforms. The IIRVs for the virtual platforms can be copies of the IIRVs for either of the two real platforms.

Two virtual customer platforms can be defined for a pair of real platforms. One of the virtual customer platforms is defined to have the S-band characteristics of the first real platform and the K-band characteristics of the second real platform. The other virtual customer platform complements the first, and is defined to have the K-band characteristics of the first real platform and the S-band characteristics of the second real platform.

3.2.3 Cross-support Service Overview

Any customer that is compatible with MA service can use forward or return support from either the TDRSS MA or the TDRSS SSA services. When the forward and return services are supplied by different TDRSS telecommunications services (e.g., MA forward and SSA return), the configuration is called a cross-support service.

3.3 Tracking and Clock Calibration Services

The SN provides tracking and clock calibration measurements for MA, SSA, and KuSA customers, as well as SSA/MA cross-support customers. Note that the SN does not provide these services for KaSA customers. Table 3-3 describes the tracking and clock calibration services available for each return link data group and mode.

a. Range. Range measurements may be provided when the customer is configured to transmit a PN code on the return link with the epoch synchronized to the epoch of the PN code received on the forward link range channel.

b. Doppler. Two-way Doppler measurements may be provided when the customer is configured such that the return link carrier is coherently related to the received forward link carrier. One-way Doppler measurements may be provided when the return link carrier is not coherently related to a forward link carrier.

c. Customer Time Transfer. The time transfer function provides a method to acquire the data necessary to update a customer platform clock. It gives the customer MOC the ability to determine the time difference between the on-board platform clock and Universal Time Coordinated (UTC). To facilitate the time transfer measurement, the customer must cause the platform to note and store the platform clock reading at the time of arrival of the epoch portion of the PN range code. The clock reading must be included in the platform telemetry for processing by the MOC. It is the MOC's responsibility to make the necessary adjustment to the customer clock using the SN-supplied data.

d. Return Channel Time Delay (RCTD). RCTD measurements, in conjunction with other data delays, enable the customer MOC to calculate the time onboard the customer platform. RCTD measures the time delay from the SN ground station antenna input to the SN ground station baseband output (at the point of time tagging within the data transport) for each I and Q channel in the return link. Unlike time transfer, RCTD can be measured with either a coherent or noncoherent service.

3.4 Testing Services

The SN provides customer test services through the functional capabilities of the SN and its supporting elements. Mutually agreed upon end-to-end tests are conducted to validate all telecommunications system functions, as defined in the applicable Interface Control Documents (ICDs). In addition, operational exercises (i.e., simulations, data flows) are conducted to ensure that operations will satisfy requirements and timelines.

a. TDRSS End-to-End Test Services. The TDRSS End-to-End Test (EET) services are provided within each SGLT at WSC. The EET provides customer projects the capability of testing the end-to-end SN data communications through a ground-based simulation of the customer platform to MOC link via TDRSS thus eliminating the need for the actual customer platform. Each EET system can simultaneously provide end-to-end testing of forward, return, and tracking services for one S-band (SSA or MA) and one Ku-band (KuSA) customer. Please note, TDRSS does not provide EET services for KaSA customers.

NOTE

> Since GRGT has no interface to support receiving and transmitting test data with the customer, end-to-end testing via GRGT is limited to local mode. Refer to Appendix N for further information on end-to-end testing.

b. TDRSS Compatibility and SN End-to-End Testing. Customers are provided a set of testing functions prior to and as part of the TDRSS services. This testing consists of the following customer platform compatibility testing and customer/SN simulation testing:

   1. Compatibility Testing. A TDRSS CTV and CTL are used to validate customer platform/TDRS RF interface compatibility prior to launch. The customer's RF ICD with the SN is one of the primary documents used to develop the Compatibility Test Plan (CTP). The TDRSS CTV/CTL emulate the TDRSS in data modulation/demodulation capabilities and provide an RF relay between the customer platform and a TDRS. Compatibility testing is performed as early as possible after fabrication of the customer platform communication devices (i.e., transceiver, transponder - either the flight model, which is preferred, or the prototype model) is completed. Compatibility tests are normally rerun following resolution of significant problems encountered during the original test or following post-test flight segment design modification. Results of these tests are formally published in the mission-specific Compatibility Test

Report. Satisfactory completion of this testing (such as end-to-end Bit Error Rate (BER) tests) and certification is required to meet the SN readiness-for-launch criteria, specifically the statement of TDRSS RF compatibility. Information about TDRSS compatibility testing is contained in TDRS and GSTDN Compatibility Test Van Functional Description and Capabilities, STDN No. 408.

2. SN Simulation Testing. Customer/SN simulation testing is performed before launch, using the customer ground facilities (customer MOC and/or data processing facility), TDRSS, RF SOC/SOC, and CTV/CTL. The purpose of pre-launch simulation testing is to validate SN performance with the customer communications equipment. Validation includes operations checkout, end-to-end tests, and fault simulation tests. SN simulation testing is also provided during the customer's mission operations to validate support procedures. Information for customers about the RF SOC/SOC is contained in STDN No. 101.6. Guidelines for this support appear in the STDN Tests and Simulation Support Plan, 530-NOP-STDN/TS, and the STDN No. 403 series document for a particular customer.

3.5 Analysis Services

3.5.1 Network Loading Analysis Services

NASA's Network Planning and Analysis System (NPAS) provides the means to assess the capability of the SN to provide service to new and changing missions in terms of resource capacity and resource allocation (scheduling). It is also used to examine future workload and architecture changes and contingency situations. This assessment is typically performed for each new mission, as well as for operational missions with changing needs, before the MSP commits to provide service. This capability is also used to aid the project/program in its telecommunications design/trade analyses. The applicable analysis is performed any time in the program/project life.

3.5.2 Communications Link and Coverage Analysis Services

NASA's Communications Link Analysis and Simulation System (CLASS) provides the capability to perform space communications link evaluations for support via the SN. Information exchange for the RF communications link and coverage analysis begins during the early customer requirements phases and continues until firm coverage requirements and flight segment design are finalized. The CLASS analysis tool is used to help achieve a flight segment telecommunications design which is compatible with the TDRSS, and will achieve the desired level of performance. Design deficiencies (including non-compliance of customer transmit constraints and performance degradations) and possible trade-offs are defined during these analyses. The results of CLASS are used to aid in the development of the RF Interface Control Document (ICD), which is a controlling input to the flight segment telecommunications specifications. The performance parameters in the ICD are defined for each RF link with a zero dB customer margin. Interim and final results of these analyses are published in the mission-specific Geometric Support Analysis and Predicted Signal Margins. Completion of these analyses is required prior to the Space Network service commitment.

3.5.3 Tracking Analysis Services

The FDF can perform tracking analysis services including customer platform trajectory and attitude computation and platform history of the on-board oscillator frequency based upon one-way Doppler data. Prelaunch orbital error analyses are performed to determine the frequency with which customer platform state vectors are needed to achieve the orbital accuracies required by the customer project.

3.6 Data Distribution/Processing Services and Data Interfaces

3.6.1 Introduction

SN data distribution/processing services can be accommodated via a number of interfaces, as shown in Figure 3-2: the Multiplexer/Demultiplexer (MDM)/IP Operational Network (IONet), the High Data Rate Service, the Local Interface (LI), the WSC Transmission Control Protocol (TCP)/Internet Protocol (IP) Data Interface Service Capability (WDISC), and on a case-by-case basis, Intermediate Frequency (IF) interfaces with the SGLTs. Table 3-4 provides an overview of the capabilities of these interfaces. All WSC return service baseband output is recorded to preserve data in the event of a downstream problem, with the exception of the LI output. For additional information about the data distribution services available to SN customers please refer to the Space Operations Management Office Services Catalog.

3.6.2 MDM/IONet

The MDM system is a full-duplex 150 channel outbound (return), 30 channel inbound (forward) interface between WSC and the NISN IONet. The Data Interface System (DIS) of STGT and WSGT each contain a MDM, as shown in Figure 3-2. The MDM blocks the outbound data in a NASA-unique 4800 bit block and then encapsulates the block in a User Datagram Protocol (UDP) packet. Similarly, the MDM un-encapsulates and de-blocks inbound data. The IONet is a routed data network that connects the WSC to various customer locations (see Appendix I for additional information on the NISN IONet). Customer ground facilities are equipped with conversion devices to perform the inverse functions of the MDM.

3.6.3 High Data Rate Service

The High Data Rate Service is a four channel outbound (return) service that is provided via the Statistical Multiplexer (STAT MUX) located in the STGT and WSGT DIS and the NISN High Rate Data System (HRDS) (a full-period leased C-band domestic communications satellite transponder), as shown in Figure 3-2 (see Appendix I for additional information on the NISN HRDS). The receive location of this service is JSC.

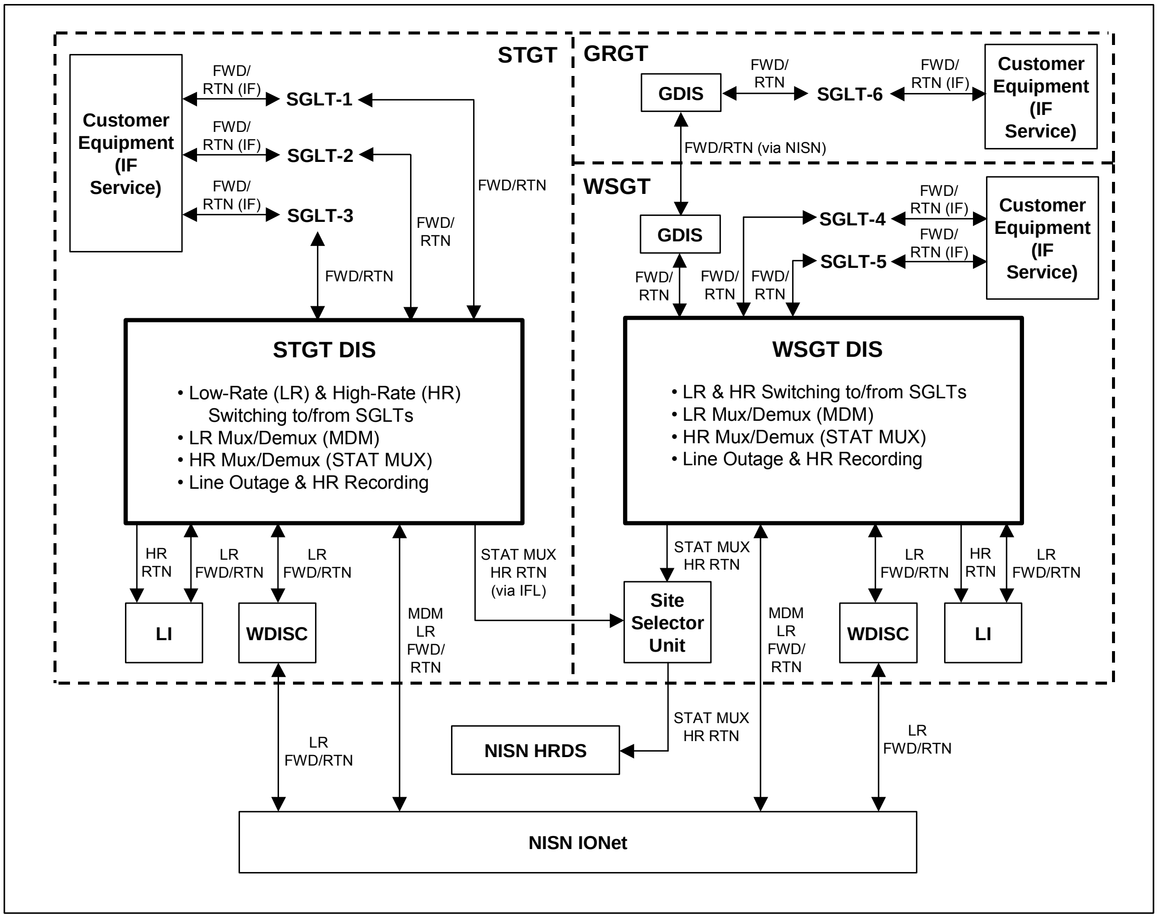


Figure 3-2. Data Distribution/Processing Services and Data Interfaces

3.6.4 Local Interface

Customers can provide interfaces at the WSC ground terminals, as shown in Figure 3-2. Local interfaces are serial clock and data.

3.6.5 WDISC

The WDISC supports customers who require TCP/IP access to the WSC for telemetry and command processing. WDISC is located at both STGT and WSGT, as shown in Figure 3-2. WDISC supports up to three simultaneous forward data channels and three simultaneous return data channels at both STGT and WSGT. WDISC customers who make use of GRGT are supported by the WDISC located at WSGT. The SN customer MOC sends commands and data playback requests to WDISC via the NISN IONet. The WDISC sends real-time IP-encapsulated data and playback data files to the MOC, also via the NISN IONet.

Table 3-4. Interface Capabilities

	Forward Service (note 7)		**Return Service** (note 7)		
Interface	**Data Rate**	**Encoding Function Provided**	**Data Rate**	**R-S Decoding Function Provided**	**Line Outage Recording**
MDM/IONet	≤ 7 Mbps per channel (note 1)	• PSK: N/A • SSA PM: Differential encoding from NRZ-L to NRZ-M, NRZ-S, BiΦ-L, BiΦ-M, or BiΦ-S	≤ 7 Mbps per channel (note 1)	N/A	Yes
High Data Rate Service	N/A	N/A	≤ 48 Mbps per channel (note 3)	N/A	Yes (note 4)
LI	≤ 7 Mbps (note 2)	• PSK: N/A • SSA PM: Differential encoding from NRZ-L to NRZ-M, NRZ-S, BiΦ-L, BiΦ-M, or BiΦ-S	≤ 300 Mbps	N/A	No
WDISC	≤ 50 kbps per channel (note 5)	• PSK or SSA PM: – Differential encoding from NRZ-L to NRZ-M, NRZ-S, BiΦ-L, BiΦ-M, or BiΦ-S – BCH encoding – Rate 1/2 convolutional encoding	≤ 512 kbps per channel (note 5)	Yes	Yes
IF Service	note 6	• PSK: N/A • SSA PM: Differential encoding from NRZ-L to NRZ-M, NRZ-S, BiΦ-L, BiΦ-M, or BiΦ-S	note 6	N/A	No

Table 3-4. Interface Capabilities (cont'd)

Notes:

1. The MDM/IONet is limited to a maximum of 7 Mbps per channel; however, due to current loading of the 9 Mbps composite, IONet bandwidth would have to be augmented to accommodate new high-rate MDM customers.
2. The current WSC data interface supports up to 7 Mbps; however, upgrades to support up to 25 Mbps are planned.
3. High Data Rate Service composite data rate $\leq$ 48 Mbps.
4. For the High Data Rate Service, high rate recording is provided for data rates between 1.5 Mbps and 50 Mbps. Additionally, rate buffering is provided at playback rates $\leq$ 48 Mbps for any High Data Rate Service recorded data rate.
5. Higher single channel forward and return data rates may be possible; however, forward rates above 50 kbps and return rates above 512 kbps have the potential to cause overloading of the WDISC. If a customer has a higher data rate requirement, workload analysis and testing will be necessary to ensure that reliable operation is possible.
6. Manual configuration required for SN IF services and support must be negotiated through MSP. All the IF services operate at 370 MHz, except for the KaSA return 650 MHz bandwidth IF service which operates at 1.2 GHz and is currently under development.
7. For SN customers using GRGT services: The GRGT – WSGT connection via NISN is currently limited in bandwidth to a 4.5 Mbps composite. New customers intending to use GRGT services services should consult with GSFC MSP regarding GRGT to WSGT bandwidth utilization. In case of a break in communications between GRGT and WSGT during a customer return service, there is no provision to record data at GRGT.

3.6.6 IF Services

SN SSA, KuSA, and KaSA forward and return IF services are available to customers on a case-by-case basis. These services require the use of the 370 MHz IF ports located in each of the WSC SGLTs, as shown in Figure 3-2. IF services are not automated. Any special purpose customer equipment used for processing data at the return IF ports and the unmodulated IF forward ports will require manual configuration. Any Doppler compensation required for acquisition and tracking of the customer signal or the forward link will be provided by the customer equipment. Note that the KaSA return IF service is currently limited to the 225 MHz bandwidth (which operates at 370 MHz). A KaSA return IF service capable of supporting the 650 MHz bandwidth is under development. This new IF return service will operate at 1.2 GHz.

3.6.7 GRGT Constraints

The GRGT – WSGT interface is through a system called the Guam Data Interface System (GDIS), with the communications connection provided via NISN. While the GDIS is capable of transporting a total composite data rate of up to 70 Mbps (where individual channel data rates must be between 100 bps and 50 Mbps), the GRGT to WSGT connection is currently limited in bandwidth to a 4.5 Mbps composite. New customers intending to use GRGT services should consult with the GSFC MSP regarding GRGT to WSGT bandwidth utilization. In case of a break in communications between GRGT and WSGT during a customer return service, there is no provision to record data at GRGT.

Section 4. Obtaining SN Services

4.1 Overview

The information in this section describes the process for obtaining SN services, which is termed the Customer Commitment Process. The objective of the Customer Commitment Process is to ensure that mission operations requirements are documented, and that services are provided to meet customer mission objectives at the lowest life cycle cost. This process incorporates the following principles:

a. Establish contact between the Space Communications and Data Systems (SCDS) Program and potential customers as early in the mission-planning phase as possible to assure those mission concepts are developed with full information about SCDS services.

b. Proactively support customers in capturing requirements by progressively refining these requirements as their mission concepts evolve.

c. Maintain flexibility in working with potential customers to analyze alternative flight/ground system concepts, innovative approaches, and cost trades.

d. Ensure objective consideration of Consolidated Space Operations Contract (CSOC) and non-CSOC services to select the approach with the lowest life cycle cost to NASA.

NASA personnel at each of the Centers provide Center-level integration and execution of mission services according to their areas of responsibility.

SCDS is responsible for overall commitment of services and facilities to support NASA and external missions. The Center Customer Commitment Managers (CCCMs) at individual centers work together to ensure all missions are supported and that support requirements are fully coordinated. The CCCMs ensure that all requirements and commitments are integrated and loading analyses are performed to ensure support is feasible and consistent with overall space operations policies and architecture.

4.2 Authorities and Responsibilities

Authority and responsibility for managing the SN, including the Customer Commitment Process Interface, has been delegated from the NASA Headquarters SCDS Program to GSFC. The Space Network Program Plan also describes these efforts.

The CCCM is the sole person at a NASA Center authorized to sign the Project Service Level Agreement (PSLA) and commit SCDS resources.

4.3 Procedures for Obtaining SN Support

The GSFC MSP is the provider for SN mission and data services. As such, the MSP plays a major role in providing cost-effective, state-of-the-art support to the customers. In order to enhance the effectiveness of carrying out this role, the MSP has implemented the MSP Commitment Process. The objective of this process is to provide a seamless interface with the customer services processes. This process is also intended to ensure all customer requirements are accurately documented and corresponding services are properly coordinated to meet the customer's mission objectives at the lowest life cycle cost.

Initially the customer project must obtain formal approval from NASA Headquarters for SN support. Then SN loading studies and preliminary analysis of the capability of the SN to provide support are completed by the MSP. A determination is made as to whether the mission requires major implementation within the MSP and whether it is a GSFC or non-GSFC project. After these determinations are made, project managers are assigned, support teams are formed, and proper documentation is prepared.

The GSFC CCCM, located in the MSP, is responsible for the commitment of all GSFC (primarily within MSP) services. The GSFC CCCM has established the MSP Customer Commitment Process to ensure all requirements and commitments are properly developed, documented and coordinated. The process is described in the MSP Customer Commitment Process, 450-PG-1310.1.1G.

4.4 System Reviews

The MSP conducts a system review of all customer flight projects in order to ensure readiness for support prior to launch. In addition, the GSFC System Review Office/Code 301 conducts additional reviews.

4.5 SN Services and Mission Support Documentation

4.5.1 General

The NASA documentation system for providing space-communication services to customers recognizes basic required documents, as follows:

a. Project Service Level Agreement (PSLA): A formal agreement between NASA and the customer for services, at a specific cost, within a specific time frame.

b. Project Commitment Document (PCD): Describes non-standard services to be implemented on behalf of one or more customers. Includes requirements, technical and cost rationale, development plan, schedule and cost profile. Applicable information is included in the PSLA.

c. Detailed Mission Requirements (DMR): Documents the customer's detailed requirements and the MSP response to the stated requirements.

d. Interface Control Document (ICD): Describes the specific interface details. ICDs will be written for each element interface. The RF ICD is a required document intended to be developed early in the design phase to drive the spacecraft RF telecommunications design. Example RF ICDs can be found at the CSOC online library Radio Frequency Interface Control Documents (RFICDs) web page at http://csoc-ddcs.csoconline.com/ollds/nf/cfm/objectView.cfm?&collection=Collection-4460.

e. Mission Operations Support Plan (MOSP): Provides operational procedures and configurations information required by MSP elements to support the mission.

f. Other documents are produced as required (e.g., mission support analysis, and compatibility test reports).

4.5.2 Space Transportation System (STS) Documentation

Support requirements for the STS and payloads embedded within the STS are published by JSC and KSC. Because of the nature of the STS hardware and procedural interfaces, the STS launch phase ground system utilization is characterized by both standardized and optional space-to-ground and ground-to-ground services. These services are negotiated and documented between the STS customer and JSC and KSC, directly, via the Payload Integration Plan (PIP) documentation system. JSC and KSC, in turn, formally negotiate with the MSP on behalf of the manifested STS customer (or customers) for each STS flight. This process is carried out by using the Program Requirements Document (PRD) and the associated methodology for integrating Orbiter and composite payload requirements for SN and ground system services before submitting these requirements for implementation by the MSP.

4.5.3 Configuration Management

Configuration control over the SN service and customer project mission support documentation will be maintained through the MSP Configuration Control Board (CCB) at the program level; project level and ad hoc CCBs are established at the project and product level, respectively. A Security Impact Evaluation Board (SIEB) has been established for the SN to manage all security-related activities. The Configuration Change Request (CCR) form is obtained from the MSP Configuration Management Office (CMO) and is used to introduce and control changes to the MSP systems.

Section 5. MA Telecommunications Services

5.1 General

5.1.1 Available Services

TDRSS MA services include forward and return telecommunications services, and tracking services. Tracking services are discussed in Section 9. This Section focuses on the RF interface between the TDRS and the customer platform. This interface is characterized by the technical requirements imposed and the operational capabilities provided by the TDRSS. The operational interfaces are described in further detail in Section 10. Data interfaces between the customer MOC and the SN are described in paragraph 3.6. The SN is currently developing a Demand Access System (DAS) that will allow expansion of the TDRSS F1-F7 MAR Data Group 1 (DG1) mode 2 services to be scheduled for extended duration or in a 'near real time' manner. This section will discuss the general MAR service capabilities; however, Appendix H should be referenced for any specific capabilities or limitations of DAS.

NOTE

Unless denoted by the TDRS fleet, the term MA is used throughout this document to denote MA services through TDRS F1-F7 and TDRS F8-F10. If the term SMA is used, these capabilities are specific to TDRS F8-F10.

NOTE

The DSMC issues Network Advisory Messages (NAMS) to provide up-to-date information on network conditions and constraints. These messages are accessible via the DSMC active NAMS web site at http://128.183.140.27/nam/wnserch.htm. At the time of publication of this revision, the TDRS F9 and F10 spacecraft are not operational. Prior to the next revision of this document, the GSFC MSP will use the NAMs as a means of letting customers know of any performance constraints associated with these spacecraft as well as any of the other TDRS.

5.1.2 Interface Definition

The RF interface between the TDRS and a customer platform is defined in terms of signal parameters, RF characteristics, and field of view.

a. The RF interface for forward service represents the transmission by a TDRS of an appropriately modulated signal at or greater than a minimum specified signal

EIRP in the direction of the desired customer platform. MA forward (MAF) service is discussed in paragraph 5.2.

b. The RF interface for return service defines a minimum received power (P_{rec}) at the TDRS antenna input for a specified data quality at the WSC receiver output. MA return (MAR) service is discussed in paragraph 5.3.

5.1.3 Customer Acquisition Requirements

Acquisition and reacquisition by the customer platform of the TDRS transmitted signal requires prediction by the customer MOC of the customer platform receive frequency over various projected time periods. Similarly, acquisition and reacquisition by the WSC of the customer platform signal requires prediction by the customer MOC of the customer platform transmitter frequency over various projected time periods. The frequency predictions are ultimately incorporated in the Schedule Order (SHO) as customer platform frequencies for the specific service support periods. Refer to section 9 for additional information on TDRSS tracking services that can assist customers to predict their local oscillator frequencies.

5.1.4 TDRSS Acquisition Support to Customers

For each scheduled TDRSS service support period, the customer requirements for signal acquisition/reacquisition and the TDRSS capabilities to aid acquisition/ reacquisition are as follows:

a. Customer Epoch Uncertainty. The maximum epoch uncertainty of the customer platform ephemeris supplied to the TDRSS should be $\pm$9 seconds for the MA LEO Field of View (LEOFOV) and the Primary Field Of View (PFOV) as defined in Table 5-2 for MAF and for MAR services.

b. Customer Frequency Uncertainty. The customer MOC must know the operating frequency of the customer platform to within $\pm$700 Hz.

c. Forward Frequency Sweep. After the start of the forward link service, the TDRSS has a forward service frequency sweep capability of $\pm$3 kHz.

d. Noncoherent Return Expanded Frequency Search. After the start of the noncoherent return link service, the TDRSS has a return service expanded frequency search capability to accommodate a customer platform's operating frequency uncertainty of up to $\pm$3 kHz for MAR DG1, SMAR DG1, and SMAR SQPSK DG2 services. Similarly, the TDRSS has a return service expanded frequency search capability to accommodate a customer platform's operating frequency uncertainty of up to $\pm$35 kHz for the SMAR BPSK and non-staggered QPSK DG2 services.

5.2 MA Forward Services

5.2.1 General

The characteristics of the data provided to the WSC interface and the RF signals provided by the TDRS to the customer platform during TDRSS MA forward services are outlined in paragraphs 5.2.2 through 5.2.5. This discussion assumes that an appropriate forward service has been scheduled and a data signal is present at the WSC interface.

5.2.2 Signal Parameters

The TDRSS MA forward service signal parameters are defined in Table 5-1. The center frequency (f_o) of the customer platform receiver must be defined by the customer MOC in its service specification code for TDRSS MA forward service (refer to paragraph 10.2.2). A description of the features inherent in the QPSK signal parameters listed in Table 5-1 are discussed in paragraph 5.2.2.1.

5.2.2.1 QPSK Signal Parameters

a. Unbalanced QPSK Modulation. The I channel is used to transmit the customer command data and is referred to as the command channel. The Q channel transmits a range signal and is referred to as the range channel. The command channel/range channel power ratio for QPSK forward service signals is +10 dB. This unbalanced QPSK modulation minimizes the power in the range channel to a level adequate for customer platform range channel acquisition and tracking. This feature increases the power in the command channel by 2.6 dB over that for balanced QPSK modulation without increasing customer platform receiver complexity, increasing customer platform command channel acquisition time, or decreasing TDRSS range tracking accuracy.

b. Spread Spectrum. TDRSS MA forward services with data rates equal to and below 300 kbps must incorporate spread spectrum modulation techniques to satisfy flux density restrictions imposed upon the TDRSS forward services by the NTIA. This modulation scheme includes separate but simultaneous command and range channels. The command channel includes a rapidly acquirable PN code and contains the forward service data. The range channel is acquired separately and contains a PN code which satisfies the range ambiguity resolution requirements. The length of the command channel PN code is 2^{10}-1, where the length of the range channel PN code is 256 times the command channel PN code length. The customer platform command channel acquisition can precede customer platform range channel acquisition; this feature permits rapid acquisition of the range channel by limiting the range channel PN code search to only 256 chip positions while the range channel PN code itself contains 261,888 chips. The PN code chip rate is coherently related to the TDRS transmit frequency in all cases. This feature permits the customer platform receiver to use the receiver PN code clock to predict the received carrier frequency, thereby minimizing receiver complexity and reducing acquisition time. 451-PN CODE-SNIP defines all the salient characteristics for the forward range and command channel PN code libraries. The agency Spectrum Manager responsible for PN code assignments will allocate a customer platform-unique PN code assignment from these libraries. The GSFC Spectrum Manager is responsible for NASA PN code assignments.

Table 5-1. TDRSS MA Forward PSK Service Signal Parameters

Parameter	Definition
TDRS transmit carrier frequency (Hz)	F
Carrier frequency arriving at customer platform (Hz) (note 1)	F_R
Carrier frequency sweep (note 3)	$\pm$3 kHz
Carrier frequency sweep duration (note 3)	120 seconds
QPSK (PN modulation enabled)	
$\frac{\text{Command channel radiated power}}{\text{Range channel radiated power}}$	+10 dB
QPSK Command Channel	
Carrier frequency (Hz)	Transmit carrier frequency (F)
PN code modulation	Phase Shift Key (PSK), + π/2 radians
Carrier suppression	30 dB minimum
PN code length (chips)	$2^{10} - 1$
PN code epoch reference	Refer to 451-PN CODE-SNIP
PN code family	Gold codes
PN code chip rate (chips/sec)	$\frac{31}{221 \times 96} \times F$
Data modulation	Modulo-2 added asynchronously to PN code
Data format (note 2)	Not Applicable
Data rate restrictions (note 2)	0.1 - 300 kbps
QPSK Range Channel	
Carrier	Command channel carrier frequency delayed π/2 radians
PN code modulation	PSK, $\pm$ π/2 radians
Carrier suppression	30 dB minimum
PN code chip rate	Synchronized to command channel PN code chip rate
PN code length	$(2^{10} - 1) \times 256$
PN code epoch reference	All 1's condition synchronized to the command channel PN code epoch
PN code family	Truncated 18-stage shift register sequences

Table 5-1. TDRSS MA Forward PSK Service Signal Parameters (Cont'd)

Notes:

1. The center frequency, f_o, of the customer platform receiver must be defined by the customer MOC in its service specification code to an integral multiple of 10 Hz. Doppler compensation will be available for $\dot{R} \leq 12$ km/sec. During periods of Doppler compensation, $F_R = f_o \pm E$ Hz; where f_o = nominal center frequency of customer platform receiver as defined by the customer MOC and $E = (70 \times \ddot{R}) + C$; $\ddot{R} \leq 15$ m/sec^2 and C = 10 Hz. During periods of Doppler compensation inhibit, WSC will round-off the customer receive frequency contained in the SHO to the nearest multiple of 221 Hz, which will result in an additional frequency error of up to 110 Hz. If Doppler compensation is inhibited after the start of the forward service, a transition profile will be initiated to slowly change the frequency from the compensate profile to this integer multiple of 221 Hz.

   Forward service Doppler compensation will not increase the effective frequency rate of change seen at the customer receiver more than 28 Hz/sec relative to the frequency for a Doppler-free carrier.
2. The forward data rate in this table is the baud rate that will be transmitted by the TDRSS (includes all coding and symbol formatting). For non-WDISC customers, forward data conditioning is transparent to the SN. These transparent operations should be performed by the customer prior to transmission to the SN data interface. Refer to paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities.
3. After the start of the MA forward service, if a customer MOC is unable to accurately define f_o (the nominal center frequency of the customer platform receiver), the forward service carrier frequency can be swept. The MA forward service frequency sweep will be initiated by the WSC at f_o-3 kHz and linearly swept to f_o+3 kHz in 120 seconds and held at f_o+3 kHz thereafter. The MA forward service frequency sweep does not impact simultaneous WSC Doppler compensation of the MA forward service carrier and PN code rate (if applicable).

c. Asynchronous Data Modulation. For data rates $\leq$ 300 kbps, the forward service data received at WSC from the NISN data transport system is directly modulo-2 added by WSC to the command channel PN code sequence. The forward service data will be asynchronous with the carrier and the PN code.

NOTE

> When the command channel does not contain any actual forward service data, the forward service command channel signal is the command channel PN code sequence.

d. Functional Configurations: A further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in section B.2.2.

e. Doppler Compensation. The TDRSS MA forward service carrier frequency (F) and the PN chip rate transmitted by a TDRS can optionally be compensated by the WSC for Doppler. When compensated, the carrier, F_R, arrives at the customer platform receiving system within a predictable tolerance (E) of f_o as defined in Table 5-1. This feature minimizes the Doppler resolution requirements of the customer platform receiver and is available continuously to facilitate reacquisition by the customer platform in the event of loss of lock of the TDRSS MA forward service signal. Customers are encouraged to utilize Doppler compensation at all times. Doppler compensation may be inhibited and the TDRSS will transmit a fixed frequency MA forward service carrier and PN code chip rate.

5.2.3 Communications Services

The TDRSS MA forward services available are listed in Table 5-2. Table 5-3 lists their salient characteristics. The definitions for the parameters listed in Table 5-3 are contained in Appendix E.

Table 5-2. TDRSS MA Forward Service

Parameter	Description	
Field of view (each TDRS)	<u>Primary (PFOV)</u> ±13 degrees conical	<u>LEO (LEOFOV)</u> ±10.5 degrees conical
Customer Ephemeris Uncertainty	≤ ± 9 sec	≤ ± 9 sec
TDRS antenna polarization	Left-hand Circular (LHC)	
TDRS antenna axial ratio (maximum)	1.5 dB over 3-dB formed beamwidth	
TDRS signal EIRP (minimum)	<u>Primary (PFOV)</u>	<u>LEOFOV</u>
SMAF via TDRS F8-F10	+40 dBW	+42 dBW
MAF via TDRS F1-F7	+34 dBW	+34 dBW
Transmit frequency (nominal) (refer to note)	$[2287.5 \pm 0.1] \times \frac{221}{240}$ MHz	
RF bandwidth (3 dB minimum)	6 MHz	
Duty factor	100 percent	
Note: The customer MOC must include the best estimate of the customer platform receiver center frequency at the start time of each scheduled service support period in its service its service specification code (refer to paragraph 10.2.2). The TDRSS MA forward service carrier frequency is then implemented by the WSC to the accuracy of the WSC frequency standard except during Doppler compensation.		

Table 5-3. Salient Characteristics for TDRSS MA Forward Services

Parameter (Note 1)	**Description** (Note 1)
$\frac{\text{Command channel radiated power}}{\text{Range channel radiated power}}$	+10 ± 0.5 dB
Modulator phase imbalance (peak)	±3 degrees (for each BPSK channel)
Modulator gain imbalance (peak)	±0.25 dB
Relative phase between command and range channels	90 ±3 degrees
Data asymmetry (peak) (Note 2)	±3 percent
Data rise time (90 percent of initial state to 90 percent of final state) (Note 2)	≤5 percent of data bit duration
Phase nonlinearity (peak)	±0.12 radian over ±2.1 MHz
Gain flatness (peak)	±1.2 dB over ±2.1 MHz
Gain slope (peak)	±0.1 dB/MHz
AM/PM	≤13 degrees/dB
PN chip jitter (rms) (including effects of Doppler compensation)	≤1 degree
Data bit jitter (peak) (Note 2)	≤1 percent
Spurious PM (rms)	≤1 degree
In-band spurious outputs	≥27 dBc
Incidental AM (peak)	≤2 percent
Phase noise (rms): 1 Hz - 10 Hz 10 Hz - 32 Hz 32 Hz - 1 kHz 1 kHz - 3 MHz	 ≤1.5 degrees ≤1.5 degrees ≤4.0 degrees ≤2.0 degrees
Command/range channel PN chip skew (peak)	≤0.01 chip
PN chip asymmetry (peak)	≤0.01 chip
PN chip rate (peak) relative to absolute coherence with carrier rate	≤0.01 chips/sec at PN code chip rate

Notes:

1. The definitions and descriptions of the salient characteristics are provided in Appendix E.
2. These values are the TDRSS contributions for data asymmetry, data transition time, and bit jitter, assuming perfect forward service data is provided to the WSC. The actual contributions by the NISN data transport system are negligible compared to those contributed by the TDRSS, since the WSC reclocks the data before it is processed by the WSC into the forward service signal.

5.2.4 Real-Time Configuration Changes

Changes to the operating conditions or configuration of a TDRS MA forward service during a scheduled service support period are usually initiated by a Ground Control Message Request (GCMR) from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the GCMR at the WSC. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning WSC response times for the GCMRs is provided in Section 10. Table 5-4 lists the MA forward service real-time configuration changes and their effects on the forward service signal.

Table 5-4. MA Forward Service Real-Time Configuration Changes

Real-Time Configuration Changes	GCMR	OPM	Forward Service Signal Interruption
Customer Receiver Center Frequency	98/04	OPM 03	Yes
Doppler Compensation Inhibit	98/08	OPM 11	No
Doppler Compensation Reinitiation	98/04	OPM 03	No
Forward Service Reacquisition (note)	98/03	OPM 02	Yes
Forward Service Sweep Request (refer to Table 5-1 note 3)	98/05	OPM 04	Yes
Data Rate	98/04	OPM 03	No
Note: Forward service reacquisition is a TDRSS reinitiation of forward link service by applying a 1 MHz frequency offset for 3 seconds to the predicted customer receive frequency specified in the customer's service specification code (refer to paragraph 10.2.2).			

5.2.5 Acquisition Scenarios

The following acquisition scenarios identify only the technical aspects of TDRSS MA forward service signal acquisition by the customer platform and do not include operational procedures related to acquisition:

a. The TDRSS MA forward service signal does not depend on a customer platform return service.

b. Prior to the start of the spatially formed TDRS MA forward service, the TDRSS MA antenna beam will be open-loop pointed in the direction of the customer platform.

c. At the start of the TDRSS MA forward service as defined by the SHO, the TDRS will radiate, in the direction of the customer platform, a signal compatible with the TDRSS MA forward service signal parameters listed in Table 5-1. The TDRS signal will be transmitted at the scheduled EIRP consistent with the values listed in Table 5-2. The signal transmitted towards the customer platform is dependent upon the customer providing an ephemeris uncertainty within the values defined in Table 5-2.

d. The customer platform receiving system will search for and acquire the command channel PN code and carrier. Normally, a customer MOC will not be transmitting forward service data to the NISN data transport system until the forward service signal has been acquired by the customer platform and the acquisition verified by the customer MOC from the customer platform return service telemetry. If the NASA fourth generation standard transponder is used, its design implementation requires that there be no data transitions during the signal acquisition process, while others may merely result in longer acquisition times.

e. The customer platform receiving system will search for and acquire the range channel PN code upon acquisition of the command channel PN code and carrier.

f. Depending upon customer platform receiving system design, upon completion of forward link acquisition and subsequent customer platform transition to signal tracking, the customer platform transmitting system may either switch to a coherent mode or remain in a noncoherent mode until commanded by the customer MOC to switch.

g. The WSC will continue Doppler compensation of the TDRSS MA forward service signal unless requested by the customer MOC to inhibit the Doppler compensation.

h. T_{acq} in the customer platform receiver is a function of the customer platform receiver design and signal-to-noise density ratio. For the purpose of an example, Table 5-5 provides the acquisition characteristics for the fourth generation transponder when receiving an MA QPSK signal. The T_{acq} values listed in Table 5-5 are contingent on the customer MOC defining the customer platform receiver center frequency, f_o, to an accuracy of $\pm$700 Hz in each service support schedule add request (SAR). The customer platform forward service acquisition time must be considered in determining the overall return service acquisition time for customer platform with a coherent mode of operation.

i. Appendix A provides example link calculations for the TDRSS MA forward service.

5.3 MA Return Services

5.3.1 General

The RF signals provided by the customer platform to the TDRS and the characteristics of data provided at the WSC interface are defined in paragraphs 5.3.2 through 5.3.5. This discussion assumes that an appropriate return service has been scheduled and a data signal is present at the TDRS interface.

Table 5-5. MA Forward Service Example Acquisition Times for the Fourth Generation NASA Standard Transponder

S/N_0 (notes 1,3)	Command Channel PN Code (note 2)	Carrier (note 2)	Range Channel PN Code (note 2)	Total (note 2)
34 dB-Hz	≤ 20 sec	≤ 5 sec	≤ 10 sec	≤ 35 sec
≥ 37 dB-Hz	≤ 7 sec	≤ 5 sec	≤ 10 sec	≤ 22 sec

Notes:

1. S/N_0 is the signal to noise density ratio (dB-Hz) at the customer platform transponder input.
2. With a probability ≥ 90%. Carrier acquisition starts after the command channel PN code has been acquired. Range channel PN code acquisition starts after the carrier has been acquired.
3. For further specific information on the Fourth Generation user transponder, reference should be made to 531-RSD-IVGXPDR.

NOTE

The F8 spacecraft has some SMA return G/T performance variations due to an MA element array and sunshield proximity problem. The F8 G/T varies based upon the normal daily TDRS diurnal cycle. This section documents the required P_{rec} values for both the F8 hot and cold conditions. The hot periods can be predicted and will occur at regular intervals with a total hot period of less than 12 hours/day. Customers attempting to schedule around the F8 hot periods, should reference the Flight Dynamics Facility Products Center web page at http://mmfd.gsfc.nasa.gov/prod_center/pc_frame_page.htm for further information on the daily TDRS-8 diurnal cycle.

5.3.2 Signal Parameters

The TDRSS MA return service signal parameters are listed in Table 5-6. The services are divided into 2 major groups, Data Group 1 (DG1) and Data Group 2 (DG2). DG1 services utilize spread spectrum modulation while DG2 services are non-spread. A description of the features inherent in the DG1 and DG2 services is discussed in 5.3.2.2 and 5.3.2.3, respectively. Within each data group, there are several types of modulation. Additionally, both data groups support coherent and noncoherent modes. A description of these general characteristics is provided in 5.3.2.1.

Table 5-6. TDRSS MA Return Service Signal Parameters

Parameter (Note 6)	**Definition** (Note 6)
DG1 (note 1)	
Transmit carrier frequency (Hz) (note 5)	F_1
Carrier (F_1) reference (Hz)	
DG1 mode 1	$\frac{240}{221} \times FR$
DG1 mode 2	Customer platform transmitter oscillator
PN code modulation	
DG1 modes 1 and 2	SQPN, BPSK (refer to Appendix B and Table 5-7)
DG1 mode 3, I channel (SMA via F8-F10)	PSK $\pm\pi/2$ radians
PN code chip rate (chips/sec)	$\frac{31}{[240 \times 96]} \times F1$
PN code length (chips)	
DG1 modes 1 and 3	$(2^{10} - 1) \times 256$
DG1 mode 2	$2^{11} - 1$
PN code epoch reference	
DG1 mode 1	
I channel	Epoch (all 1's condition) synchronized to epoch (all 1's condition) of received forward service range channel PN code
Q channel (note 3)	Epoch delayed x + 1/2 PN code chips relative to I channel PN code epoch
DG1 mode 2	Not Applicable
DG1 mode 3, I channel	Same as DG1 mode 1 (I channel)
PN code family	
DG1 mode 1	Truncated 18-stage shift register sequences
DG1 mode 2	Gold codes
Data modulation:	
DG1 modes 1 and 2	Modulo-2 added asynchronously to PN code
DG1 mode 3: (SMA via F8-F10)	
I channel	Modulo-2 added asynchronously to PN code
Q channel	PSK $\pm\pi/2$ radians

Table 5-6. TDRSS MA Return Service Signal Parameters (Cont'd)

Parameter (Note 6)	Definition (Note 6)
DG1 (note 1)	
Periodic convolutional interleaving (note 4)	Recommended for baud rates > 300 kbps
Data Format	NRZ-L, NRZ-M, NRZ-S
Symbol Format	NRZ, Biϕ-L (note 5)
DG1 mode 1 data rate restrictions (rate 1/2 convolutional encoded)	
Total (note 1)	0.1 - 300 kbps
I channel	0.1 - 150 kbps
Q channel	0.1 - 150 kbps
DG1 mode 2 data rate restrictions (rate 1/2 convolutional encoded)	
Total (note 1)	1 - 300 kbps
I channel	1 - 150 kbps
Q channel	1 - 150 kbps
DG1 mode 3 data rate restrictions (rate 1/2 convolutional encoded) (SMA via F8-F10)	
Total (note 1)	I (max) + Q (max)
I channel	0.1 - 150 kbps
Q channel	1 kbps – 1.5 Mbps
DG1 $\frac{\text{Q channel power}}{\text{I channel power}}$ restrictions (note 2)	
Single data source-alternate I/Q bits (SMA via F8-F10)	1:1
Single data source-identical data	1:1 to 4:1
Single data source-single data channel	NA
Dual data sources	1:1 to 4:1
DG2 (SMAR via F8-F10) (note 1)	
Transmit carrier frequency (note 5)	F_2
Carrier (F_2) reference (Hz)	
DG2 Coherent	$\frac{240}{221} \times F_R$
DG2 Noncoherent	Customer platform oscillator
Data modulation (note 1)	BPSK, SQPSK, or QPSK (refer to Appendix B and Table 5-7)

Table 5-6. TDRSS MA Return Service Signal Parameters (Cont'd)

Parameter (Note 6)	Definition (Note 6)
DG2 (SMAR via F8-F10) (note 1)	
Periodic convolutional interleaving (note 4)	Recommended for baud rates > 300 kbps
Symbol format	NRZ, Biϕ-L
Data format	NRZ-L, NRZ-M, NRZ-S
Data rate restrictions (rate 1/2 convolutional encoded)	
Total (note 1)	I (max) + Q (max)
I channel	1 kbps – 1.5 Mbps
Q channel	1 kbps – 1.5 Mbps
DG2 $\frac{\text{I channel power}}{\text{Q channel power}}$ restrictions	
Single data source-alternate I/Q bits	1:1
Single data source-alternate I/Q encoded symbols	1:1
Single data source-single data channel	NA
Dual data sources	1:1 to 4:1

Notes:

1. Customer platform data configurations, including specific data rate restrictions for coding and formatting, are defined in Table 5-7 for TDRSS MA return service (refer also to Appendix B). Unless otherwise stated, the data rate restrictions given in this table assume rate 1/2 convolutional encoding and NRZ formatting.
2. For DG1, the Q/I power parameter range can vary from 1:1 to 4:1 continuously during specification of applicable parameter values in the DSMC scheduling database and during real-time service reconfiguration. However if this parameter is respecified in schedule requests to the DSMC (refer to paragraph 10.2.2), it is expressed as the ratio of two single-digit integers.
3. The Q channel PN code sequence must be identical to the I channel PN code sequence; but, offset x + 1/2 PN chips, where x >20,000. The value of x is defined by the PN code assignment for a particular customer platform (refer to 451-PN CODE-SNIP).
4. Periodic convolutional interleaving (PCI) recommended on S-band return services for channel baud rates > 300 kbps. Biphase symbol formats are not allowed with PCI. When interleaving is not employed for channel baud rates > 300 kbps, S-band return performance may not be guaranteed.
5. The center frequency, f_o, of the customer platform transmitter must be defined by the customer MOC in its service specification code to an integral multiple of 10 Hz.
6. Unless otherwise noted, all data rate values (are to be interpreted as data bit rates, and not as data symbol rates.

Table 5-7. MA/SMA Return Service Configurations

Return Service Configuration[10]				Source Data Rate Restrictions and Availability[9]					
				DG1 Mode				DG2 Mode (SMA only)	
				1[1] and 2[1,4,8]		3[2] (SMA only)		Coherent[3] and Noncoherent[3,4]	
				Data format	Data rate	Data format	Data rate	Data format	Data rate
Single Data Source	BPSK	Rate 1/2 coded		NRZ	≤150 kbps[1]	-	-	NRZ	1 kbps – 1.5 Mbps[5]
				NRZ with biphase symbols	≤75 kbps[1]			NRZ with biphase symbols	1 kbps – 0.75 Mbps[5,6]
		Rate 1/3 coded		-	-	-	-	NRZ	1 kbps – 1 Mbps[5]
								NRZ with biphase symbols	1 kbps – 0.5 Mbps[5,6]
		Uncoded		[7]	[7]	-	-	[7]	[7]
	SQPN	Identical I & Q channel data	Rate 1/2 coded	NRZ	≤150 kbps	-	-	-	-
				NRZ with biphase symbols	≤75 kbps				
			Uncoded	[7]	[7]	-	-	-	-
	SQPSK	Rate 1/2 coded alternate I/Q encoded symbols		-	-	-	-	NRZ	1 – 300 kbps
	SQPN[1] or SQPSK[3]	Alternating I/Q data	Individually rate 1/2 coded	NRZ	≤300 kbps (SMA only)	-	-	NRZ	1 kbps – 3 Mbps[5]
			Individually rate 1/3 coded	-	-	-	-	NRZ	1 kbps – 2 Mbps[5]
			Uncoded	[7]	[7]	-	-	[7]	[7]
Dual Data Sources (data rates are for each source separately)	SQPN[1], QPSK[2,3] or SQPSK[3]	Rate 1/2 coded		NRZ	≤150 kbps	NRZ	I: 0.1-150 kbps Q: 1 kbps – 1.5 Mbps	NRZ	1 kbps – 1.5 Mbps[5]
				NRZ with biphase symbols	≤75 kbps	NRZ with biphase symbols	I: 0.1-75 kbps Q: 1 kbps – 0.75 Mbps[5,6]	NRZ with biphase symbols	1 kbps – 0.75 Mbps[5,6]
		Rate 1/3 coded		-	-	NRZ	Q: 1 kbps – 1Mbps	NRZ	1 kbps – 1 Mbps[5]
						NRZ with biphase symbols	1 kbps – 0.5 Mbps[5,6]	NRZ with biphase symbols	1 kbps – 0.5 Mbps[5,6]
		Uncoded		[7]	[7]	[7]	[7]	[7]	[7]

Table 5-7. MA/SMA Return Service Configurations (cont'd)

Notes:

✓ Configuration supported

\- Configuration not supported

1. For DG1 mode 1 and 2 configurations, where the minimum source data rates are 0.1 kbps for DG1 mode 1 and 1 kbps for DG1 mode 2:
   a. For data on a single I or Q channel, but not both channels: BPSK modulation is used where the data is modulo-2 added to the PN code.
   b. For data on both the I and Q channels: SQPN modulation is used and the SN supports I:Q power ratios of 1:1 to 1:4 for all the configurations, except the alternating I and Q data bit configuration, which requires a balanced I:Q power ratio.
   c. For the alternating I/Q data bit configuration: the SN requires the I channel lead the Q channel by a half symbol. Similarly, the SN requires the I and Q channels be independently differentially formatted (-M,-S).
2. For DG1 mode 3 configurations:
   a. The modulation is QPSK, where the I channel data is modulo-2 added to the PN code, and the Q channel data directly modulates the carrier at $+\pi/2$ radians.
   b. The SN supports I:Q power ratios of 1:1 to 1:4.
   c. Rate 1/3 coding is supported for the Q channel only. (Rate 1/2 coding is supported on both the I and Q channels.)
3. For DG2 configurations:
   a. For single data source configurations with data on one channel: BPSK modulation is used.
   b. For single data source configurations with data on both channels: SQPSK modulation and an I:Q power ratio of 1:1 is used. For the alternate I/Q bit configuration, the SN requires the I and Q channels be independently differentially formatted (-M,-S).
   c. For dual data source configurations: SQPSK must be used when there are identical baud rates on the I and Q channels (see paragraph 5.3.2.1.b); QPSK is used for all other configurations; for both SQPSK and QPSK, either an I:Q power ratio of 1:1 or 4:1 is supported. For unbalanced QPSK, the I channel must contain the higher data rate and when the data rate on the I channel exceeds 70 percent of the maximum allowable data rate, the Q channel data rate must not exceed 40 percent of the maximum allowable data rate on that Q channel.
4. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of ± 700 Hz. If a customer cannot accurately define their transmit frequency to within ± 700 Hz, a customer can request a reconfiguration which would expand the oscillator frequency search to ± 3 kHz for DG1 and SQPSK DG2 configurations and ± 35 kHz for BPSK and QPSK DG2 configurations after the start of service.
5. Periodic convolutional interleaving (PCI) is recommended on S-band return service for channel baud rates > 300 kbps. When interleaving is not employed for channel baud rates > 300 kbps, S-band performance may not be guaranteed.
6. Biphase symbol formats are not allowed with PCI. Use of biphase symbol formats on S-band services at baud rates > 300 kbps should be coordinated with the GSFC MSP.
7. For all configurations and modes, the SN is capable of providing SMA support of uncoded links; however, performance is not guaranteed in RFI and must be coordinated with the GSFC MSP.
8. The SN is currently developing a Demand Access System (DAS) that will allow expansion of the TDRSS F1-F7 MAR Data Group 1 (DG1) mode 2 services to be scheduled for extended duration or in a 'near real time' manner. Refer to Appendix H for further information.
9. Unless otherwise noted, all data rates are to be interpreted as data bit rates, and not as data symbol rates. Refer to paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities.
10. Appendix B describes the functional configurations and associated I-Q channel and data polarity ambiguities. Additionally, Figure B-10 depicts the SN supported convolutional coding schemes.

5.3.2.1 General Modulation and Coherent/Noncoherent Description

a. SQPN Modulation. SQPN modulation is used to prevent simultaneous transitions of the I and Q PN sequences. For SQPN modulation, the PN chips of the I and Q channel are staggered by a 1/2 chip. For data configurations that use two PN spread channels, SQPN modulation must be used.

b. SQPSK Modulation. SQPSK modulation staggers one channel with respect to the other to prevent synchronous transitions. For non-spread signal configurations with identical I and Q symbol rates that are NRZ symbol formatted, SQPSK modulation must be used. The symbols of the Q channel are delayed 1/2 symbol relative to the I channel. For non-spread signal configurations that use biphase symbol formatting on either channel and the baud rate of the two channels are identical, SQPSK modulation is used and the transitions of one channel occur at the mid-point of adjacent transitions of the other channel.

c. QPSK Modulation. QPSK modulation is available when there is no relation between the I and Q channel transitions. For dual data source configurations, in which one or both channels are not spread and SQPSK is not required, QPSK modulation is used.

d. BPSK Modulation. BPSK modulation is available for single data source configurations that use only one channel of the link.

NOTES

For SQPN and SQPSK modulation, the spectral characteristics of a customer platform saturated power amplifier will, to a great degree, retain the spectral characteristics of the band-limited input signal to that amplifier. This should result in better control of out-of-band emissions, which, in turn, provides more efficient communications and less interference to customer platform using adjacent frequency channels on the TDRS links.

e. Coherent Mode. For coherent modes, the customer platform transmitted return link carrier frequency and PN code clock frequency (if applicable) are derived from the customer platform received forward link carrier frequency. For coherent PN spread return links, the return PN code length is identical to the length of the received forward service range channel PN code. The customer return I channel PN code epoch is synchronized with the epoch of the received forward service range channel PN code. Two-way Doppler measurements and range measurements (if PN spread) are available.

f. Noncoherent Mode. For noncoherent modes, the customer platform transmitted return link carrier frequency and PN code clock frequency (if applicable) are derived from an on-board local oscillator. The customer platform transmit frequency for noncoherent service must be defined by the customer MOC to an accuracy of ±700 Hz in its configuration code when requesting TDRSS MA return service (refer to paragraph 10.2.2). For customers whose frequency uncertainty is greater than ±700 Hz, an expanded frequency search capability is available after service start.

g. Asynchronous Data Modulation. The data modulation is asynchronous to the carrier and the channel PN code (if applicable). This prevents Doppler variations of the forward service carrier and PN code frequencies from affecting the return service data rate.

5.3.2.2 DG1 Signal Parameters.

DG1 signal parameters are subdivided into three modes of operation, DG1 modes 1, 2, and 3. For all DG1 modes, the PN code clock must be coherently related to the transmitted carrier frequency. This feature permits the customer platform transmitter to use a common source for generating the carrier and the PN code clock frequencies. 451-PN CODE-SNIP defines all the salient characteristics for the DG1 PN code libraries. The agency Spectrum Manager responsible for PN code assignments will allocate a customer platform-unique PN code assignment from these libraries. The GSFC Spectrum Manager is responsible for NASA PN code assignments. The three DG1 modes are distinguished as follows:

a. DG1 Mode 1. DG1 mode 1 must be used when range and two-way Doppler measurements (coherent transponder operations) are required concurrently with return service low-rate data transmission. Return service signal acquisition by the WSC for DG1 mode 1 is possible only when the scheduled TDRSS (MA or SSA) forward service signal is acquired by the customer platform and the PN code and carrier transmitted by the customer platform are coherently related to the forward service signal from the TDRS. If the TDRSS forward service signal becomes unavailable to the customer platform (the forward service is time-shared with other customer platforms), the customer platform transmitter must switch to noncoherent transmitter operation (DG1 mode 2) (refer to paragraph 5.3.5.c.2). In order to reacquire the DG1 mode 2 signal, the return service must be reconfigured. The I and Q channel PN codes are generated from a single code generator. For DG1 mode 1 operation, the I and Q channel PN codes are identical but are offset by at least 20,000 chips. This separation is adequate for TDRSS to identify each data channel unambiguously without requiring a unique PN code for each channel.

b. DG1 Mode 2. DG1 mode 2 will be used when WSC return service signal acquisition is necessary without the requirement for prior customer platform signal acquisition of the TDRSS (MA or SSA) forward service (noncoherent transponder operation). The customer platform transmit frequency for DG1 mode 2 service must be defined by the customer MOC to an accuracy of ±700 Hz in its configuration code when requesting TDRSS MA return service (refer to paragraph 10.2.2). For customers whose frequency uncertainty is greater than ±700 Hz, an expanded frequency search capability of ±3 kHz is available. For DG1 mode 2, the I and Q channel PN codes are unique 2^{11}-1 Gold Codes.

NOTE

The SN is currently developing a Demand Access System (DAS) that will allow expansion of the TDRSS F1-F7 MAR DG1 mode 2 services to be scheduled for extended duration or in a 'near real time' manner. Refer to Appendix H for further information.

c. DG1 Mode 3 (SMA via F8-F10). DG1 mode 3 can be used when range and two-way Doppler measurements (coherent transponder operations) are required concurrently with return service high-rate data transmission. Restrictions on DG1 mode 3 signal acquisition are identical to those for DG1 mode 1. In DG1 mode 3, the Q channel must contain only data and no PN code.

d. Functional Configurations. Table 5-7 lists the DG1 MA return service functional configurations and a further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in section B.3.2.

5.3.2.3 DG2 Signal Parameters

DG2 signal parameters are subdivided into two modes of operation, DG2 coherent and noncoherent. DG2 must be used when the return service data rate equipment exceeds the capability of DG1 operations. DG2 operations cannot provide TDRSS range tracking because PN code modulation is not used. The two DG2 modes are distinguished as follows:

a. DG2 Coherent (SMA via F8-F10). Return service signal acquisition by the WSC for DG2 coherent is possible only when the scheduled TDRSS (SSA or MA) forward service signal is acquired by the customer platform and the carrier transmitted by the customer platform are coherently related to the forward service signal from the TDRS. TDRSS two-way Doppler tracking can be provided when the DG2 carrier is coherently related to the TDRSS (SSA or MA) forward service carrier frequency.

b. DG2 Noncoherent (SMA via F8-F10). The DG2 carrier is independent of the TDRSS (SSA or MA) forward service carrier frequency. The customer platform transmit frequency for DG2 noncoherent service must be defined by the customer MOC to an accuracy of $\pm$700 Hz in its service specification code when requesting TDRSS SMA return service (refer to paragraph 10.2.2). For customers whose frequency uncertainty is greater than $\pm$700 Hz, an expanded frequency search capability of $\pm$3 kHz for SQPSK DG2 services and $\pm$35 kHz for BPSK and QPSK DG2 services is available after start of the return service.

c. Functional Configurations. Table 5-7 lists the DG2 SMA return service functional configurations and a further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in section B.3.3.

5.3.3 Communication Services

To obtain TDRSS MA return service performance defined in this paragraph, the customer platform transmitted signal must meet the requirements found in Table 5-8 and signal characteristics specified in Table 5-11. The TDRSS MA return service performance defined in this paragraph also assumes return service operation in an Additive White Gaussian Noise (AWGN) environment. Appendix G discusses performance degradations to the TDRSS MA return service due to RFI. Example link calculations are provided in Appendix A. TDRSS MAR supports customers with an ephemeris uncertainty as defined in Table 5-8 and dynamics, described as non-powered flight and powered flight (SMAR only), as defined in Table 5-9.

5.3.3.1 Acquisition

The MAR service supports acquisition for customer platforms operating under non-powered flight dynamics as defined in Table 5-9. MAR acquisition will be protected against false WSC lock to: interfering customer platform PN codes, customer platform PN code sidelobes, and carrier recovery. The MAR total channel acquisition times (T_{acq}) are given in Table 5-8 and are the sum of the following:

a. PN (DG1 only) and carrier acquisition time

b. Symbol/Decoder synchronization time or Symbol/Deinterleaver/Decoder synchronization time (if deinterleaving is applicable).

T_{acq} assumes that the customer platform return service signal is present at the WSC at the start time of the scheduled return service support period and the process is described below.

a. PN code (if applicable) and carrier acquisition will commence upon the start of the scheduled return service support period.

b. After PN code (if applicable) and carrier acquisition is achieved, TDRSS tracking services data is available.

c. Symbol/Decoder and Symbol/Deinterleaver/Decoder synchronization times will be measured from the time when the carrier acquisition is achieved to the time when the decoder synchronization is achieved. Decoder synchronization is achieved when the Viterbi decoder has selected and implemented the correct blocking of the input symbols (into groups of (G1,G2) symbol pairs for rate 1/2 codes, or (G1,G2,G3) symbol triplets for rate 1/3 codes).

Table 5-8. TDRSS MA Return Service

Parameter (Note 7)	**Description** (Note 7)	
Field of view F(OV) (each TDRS)	Primary (PFOV) $\pm$13 degrees conical	LEO (LEOFOV) $\pm$10.5 degrees conical
Customer Ephemeris Uncertainty (along the customer orbital track)	$\le \pm$ 9 sec	$\le \pm$ 9 sec
TDRS antenna polarization	LHC	
TDRS antenna axial ratio (maximum)	1.5 dB over 3-dB formed beamwidth	
Receive frequency (nominal) (see paragraph 5.3.3.5.b)	2287.5 $\pm$0.1 MHz	
RF bandwidth (3dB, minimum)	6 MHz	
10^{-5} Bit Error Rate (notes 1, 2, 7)		
Orbital Dynamics	Powered (SMAR only) and non-powered flight dynamics (defined in Table 5-9)	
Minimum Required P_{rec} for Rate 1/2 convolutional coding:	All P_{rec} values are in dBW; dr is data rate in bps	
	PFOV	LEOFOV
DG1 modes 1 and 2:		
F1-F7	$-220.9 + 10\log_{10}(dr)$	$-221.8 + 10\log_{10}(dr)$
F8 (cold), F9, F10 (note 6)	$-222.4 + 10\log_{10}(dr)$	$-223.7 + 10\log_{10}(dr)$
F8 (hot) (note 6)	$-219.0 + 10\log_{10}(dr)$	$-220.4 + 10\log_{10}(dr)$
DG1 mode 3 (SMAR only via F8-F10)		
I channel (F8 cold, F9, F10) (note 6)	$-222.4 + 10\log_{10}(dr)$	$-223.7 + 10\log_{10}(dr)$
I channel (F8 hot) (note 6)	$-219.0 + 10\log_{10}(dr)$	$-220.4 + 10\log_{10}(dr)$
Q channel (F8 cold, F9, F10) (note 6)		
Data rate $\le$ 1 Mbps	$-222.8 + 10\log_{10}(dr)$	$-224.1 + 10\log_{10}(dr)$
Data rate > 1 Mbps	$-222.1 + 10\log_{10}(dr)$	$-223.4 + 10\log_{10}(dr)$
Q channel (F8 hot) (note 6)		
Data rate $\le$ 1 Mbps	$-219.4 + 10\log_{10}(dr)$	$-220.8 + 10\log_{10}(dr)$
Data rate > 1 Mbps	$-218.7 + 10\log_{10}(dr)$	$-220.1 + 10\log_{10}(dr)$
DG2 (SMAR only via F8 cold, F9, F10) (note 6)		
Data rate $\le$ 1 Mbps	$-222.8 + 10\log_{10}(dr)$	$-224.1 + 10\log_{10}(dr)$
Data rate > 1 Mbps	$-222.1 + 10\log_{10}(dr)$	$-223.4 + 10\log_{10}(dr)$

Table 5-8. TDRSS MA Return Service (Cont'd)

Parameter (Note 7)	**Description** (Note 7)	
10^{-5} Bit Error Rate (notes 1, 2, 7) (cont'd)		
Minimum Required P_{rec} for Rate 1/2 convolutional coding (cont'd):	All P_{rec} values are in dBW; dr is data rate in bps	
DG2 (SMAR only via F8 hot) (note 6)		
Data rate ≤ 1 Mbps	$-219.4 + 10\log_{10}(dr)$	$-220.8 + 10\log_{10}(dr)$
Data rate > 1 Mbps	$-218.7 + 10\log_{10}(dr)$	$-220.1 + 10\log_{10}(dr)$
Minimum Required P_{rec} for Rate 1/3 convolutional coding:	All P_{rec} values are in dBW; dr is data rate in bps	
DG1 mode 3, Q channel (SMAR only via F8 cold, F9, F10) (note 6)	PFOV	LEOFOV
Data rate ≤ 1 Mbps	$-223.1 + 10\log_{10}(dr)$	$-224.4 + 10\log_{10}(dr)$
Data rate > 1 Mbps	$-222.5 + 10\log_{10}(dr)$	$-223.8 + 10\log_{10}(dr)$
DG1 mode 3, Q channel (SMAR only via F8 hot) (note 6)		
Data rate ≤ 1 Mbps	$-219.7 + 10\log_{10}(dr)$	$-222.1 + 10\log_{10}(dr)$
Data rate > 1 Mbps	$-219.1 + 10\log_{10}(dr)$	$-220.5 + 10\log_{10}(dr)$
DG2 (SMAR only via F8 cold, F9, F10) (note 6)		
Data rate ≤ 1 Mbps	$-223.1 + 10\log_{10}(dr)$	$-224.4 + 10\log_{10}(dr)$
Data rate > 1 Mbps	$-222.5 + 10\log_{10}(dr)$	$-223.8 + 10\log_{10}(dr)$
DG2 (SMAR only via F8 hot) (note 6)		
Data rate ≤ 1 Mbps	$-219.7 + 10\log_{10}(dr)$	$-222.1 + 10\log_{10}(dr)$
Data rate > 1 Mbps	$-219.1 + 10\log_{10}(dr)$	$-220.5 + 10\log_{10}(dr)$
Acquisition (note 3):		
Orbital dynamics	free-flight dynamics only (defined in Table 5-9)	
Total Channel Acquisition Time (assumes the customer return service signal is present at the WSC at the start time of the return service support period)	Sum of the following: 1. PN (DG1 only) and carrier acquisition time 2. Symbol/Decoder synchronization time or Symbol/Deinterleaver/Decoder synchronization time (if deinterleaving is applicable)	

Table 5-8. TDRSS MA Return Service (Cont'd)

Parameter (Note 7)	**Description** (Note 7)	
Acquisition (note 3) (cont'd):		
PN Code (if applicable) and Carrier Acquisition		
P_{rec}	Primary FOV	LEOFOV
F1-F7	$\geq$-192.2 dBW or consistent with the P_{rec} for BER, whichever is greater	$\geq$-193.1 dBW or consistent with the P_{rec} for BER, whichever is greater
F8 cold, F9, F10 (note 6)	$\geq$-193.7 dBW or consistent with the P_{rec} for BER, whichever is greater	$\geq$-195.0 dBW or consistent with the P_{rec} for BER, whichever is greater
F8 hot (note 6)	$\geq$-190.3 dBW or consistent with the P_{rec} for BER, whichever is greater	$\geq$-191.7 dBW or consistent with the P_{rec} for BER, whichever is greater
Acquisition Time ($P_{acq} \geq$ 90%)		
Coherent operations	$\leq$ 1 sec	
Noncoherent operations with frequency uncertainty (note 4):		
$\leq \pm$ 700 Hz	$\leq$ 1 sec	
$\leq \pm$ 3 kHz	$\leq$ 3 sec	
$\leq \pm$ 35 kHz	$\leq$ 3 sec	
Channel Decoder/Symbol Synchronization Acquisition (note 5):		
Minimum data bit transition density	$\geq$ 64 randomly distributed data bit transitions within any sequence of 512 data bits	
Number of consecutive data bits without a transition	$\leq$ 64	
P_{rec} (dBW)	consistent with the P_{rec} for BER	
Acquisition time (in seconds) with > 99% probability:		
Biphase	$\leq$ 1100/(Channel Data Rate in bps)	
NRZ	$\leq$ 6500/(Channel Data Rate in bps)	

Table 5-8. TDRSS MA Return Service (Cont'd)

Parameter (Note 7)	**Description** (note 7)
Acquisition (note 3) (cont'd):	
Channel Symbol/Deinterleaver(PCI)/Decoder Synchronization Acquisition (note 5):	
Minimum data bit transition density	$\geq$ 64 randomly distributed data bit transitions within any sequence of 512 data bits
Number of consecutive data bits without a transition	$\leq$ 64
Prec (dBW)	consistent with the P_{rec} for BER
Acquisition time (in seconds) with >99% probability:	
Rate 1/2 coding	Average: $\leq$ 36000/(Channel Data Rate in bps) Maximum: $\leq$ 66000/(Channel Data Rate in bps)
Rate 1/3 coding	Average: $\leq$ 26000/(Channel Data Rate in bps) Maximum: $\leq$ 46000/(Channel Data Rate in bps)
Signal Tracking	
Orbital dynamics	During Free Flight refer to paragraph 5.3.3.3.a During Powered Flight (SMAR only) refer to paragraph 5.3.3.3.b
Reacquisition (powered (SMAR only) and non-powered flight)	refer to paragraph 5.3.3.4
Duty factor	100 percent

Notes:

1. The BER is for a customer platform transmitting a signal on an AWGN channel which complies with the constraints defined in Table 5-11. Refer to Appendix G for a discussion of the additional degradation potentially applicable to TDRSS MA return performance service due to S-band RFI.
2. The required customer P_{rec} must meet the P_{rec} for BER or signal acquisition, whichever is greater. Paragraph 5.3.3.2.b provides the required P_{rec} description for each possible MAR data configuration. Refer to Appendix A, paragraph A.4, for a definition of P_{rec}. The minimum required P_{rec} equations for BER produce the minimum P_{rec} for a given data rate for all possible signal characteristics. CLASS analysis will produce a more accurate performance projection based upon desired customer signal characteristics, such as data rate, data type, and jitter values. The P_{rec} equations for BER include 2 dB for self and mutual interference degradation. Appendix O provides an assessment of self and mutual interference in the TDRSS MA environment at 2287.5 MHz. The amount of self and mutual interference included in a customer's MAR/SMAR link budget should be negotiated with the GSFC MSP. SN support may be possible for customers whose P_{rec} is less than the required P_{rec} for 10^{-5} BER performance as long as the customer is willing to accept support on a best-effort basis and less than 100 percent coverage. Any customer interested in receiving this marginal SN coverage shall be required to negotiate all support with the GSFC MSP. In general, customer platforms should be designed to the most limiting TDRS to ensure SN support can be provided.

Table 5-8. TDRSS MA Return Service (Cont'd)

Notes (Cont'd):

3. For PN code (if applicable) and carrier acquisition, the minimum P_{rec} value listed applies to the total $(I+Q)P_{rec}$. For carrier acquisition of SMAR SQPSK DG2 and noncoherent ±35 kHz expanded frequency uncertainty DG2 configurations, the total $(I+Q)P_{rec}$ must be ≥ -183.0 dBW for LEOFOV or ≥ -181.7 dBW for Primary FOV when operating with F8(cold), F9, F10. Similarly, when operating with F8 (hot) the total $(I+Q)P_{rec}$ must be ≥ -179.7 dBW for LEOFOV or ≥ -178.3 dBW for Primary FOV during carrier acquisition of SMAR SQPSK DG2 and noncoherent ±35 kHz expanded frequency uncertainty DG2 configurations. In all cases, acquisition requires the P_{rec} to also be consistent with the P_{rec} required for BER.
4. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of ± 700 Hz. If a customer cannot accurately define their transmit frequency to within ± 700 Hz, a customer can request a reconfiguration which would expand the oscillator frequency search to ± 3 kHz for DG1 and SQPSK DG2 configurations and ± 35 kHz for BPSK and non-staggered QPSK DG2 configurations after the start of service.
5. For symbol/decoder synchronization and symbol/deinterleaver/decoder synchronization, the minimum symbol transition density and consecutive symbols without a transition must meet the specifications defined in Table 5-11. It is recommended that customers use G_2 inversion to increase symbol transition density. Additionally, biphase symbol formatting increases symbol transition density.
6. The F8 spacecraft has some SMA return G/T performance variations due to an MA element array and sunshield proximity problem. The G/T varies based upon the normal daily TDRS diurnal cycle. The hot periods can be predicted and will occur at regular intervals with a total hot period of less than 12 hours/day. Customers attempting to schedule around hot periods, should reference the Flight Dynamics Facility Products Center web page at http://mmfd.gsfc.nasa.gov/prod_center/pc_frame_page.htm for further information on the daily TDRS-8 diurnal cycle.
7. All data rate values (and notes which modify these values, based upon specific signal format and encoding restrictions) are to be interpreted as data bit rates, and not as data symbol rates.

Table 5-9. Customer Dynamics Supported through TDRSS MAR Service

Parameter	**Non-powered Flight Dynamics (MAR and SMAR)**	**Powered Flight Dynamics (SMAR only)**
$\dot{R}$	≤ 12 km/sec	≤ 15 km/sec
$\ddot{R}$	≤ 15 m/sec^2	≤ 50 m/sec^2
$\dddot{R}$	≤ 0.02 m/sec^3	≤ 2 m/sec^3

d. After symbol/decoder and symbol/deinterleaver/decoder synchronization is achieved, MA return service channel data is available at the WSC interface.

e. To minimize return data loss, it is recommended that the customer platform transmit idle pattern on its data channels until after it has observed (via the UPD data) that the WSC has completed all of its data channel signal acquisition processes.

f. Requirements for bit error probability and symbol slipping take effect at the time decoder synchronization is achieved.

NOTE

Acquisition times will be reduced when data and symbol transition density values are higher than the minimum required.

5.3.3.2 Bit Error Rate (BER)

Table 5-8 provides P_{rec} equations that will result in a customer achieving a BER of 10^{-5} for TDRSS compatible signals. The BER P_{rec} equations are applicable for either powered (SMAR only) or non-powered flight dynamics and the following conditions:

a. Data Encoding. Convolutional encoding (rate 1/2 or rate 1/3 (SMAR only)) should be used for all customer platform MA transmissions both to minimize P_{rec} and as an RFI mitigation technique. Detailed coding design is described in Appendix B. Reed-Solomon decoding is available to WDISC customers; typical, performance is given in Appendix K.

NOTE

For all configurations and modes, the SN is capable of providing SMAR support of uncoded links; however, performance is not guaranteed in RFI and must be coordinated with the GSFC MSP.

b. Received Power. P_{rec} is in units of dBW. The customer project, in determining its design requirements for minimum customer spacecraft EIRP, must take into account customer platform transmit antenna pointing losses, the space loss between the customer platform and the TDRS, and the polarization loss incurred between the customer platform transmit antenna and the TDRS receive antenna. The maximum TDRS receive antenna axial ratio is given in Table 5-8 (also refer to Appendix A). For DG1 and DG2 services, the following conditions apply:

   1. Balanced Power Single Data Source-Identical Data on the I and Q Channels (DG1 mode 1 and 2 only). For a customer platform synchronously transmitting identical data on the I and Q channels (single

data source – identical data) with a balanced I and Q channel power division, the total (I+Q) P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 5-8, where dr is the single data source data rate. Refer to Appendix B for further information on this data configuration.

2. Balanced Power Single Data Source-Alternate I/Q Bits (SMAR DG1 mode 1 and 2 and DG2). For a customer platform transmitting alternate I and Q data bits from a data source (single data source-alternate I/Q bits), the total (I+Q)P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 5-8, where dr is the single data source data rate prior to separation into the I and Q channels. The Q/I (power) must be equal to 1:1. Refer to Appendix B for further information on this data configuration.

3. Balanced Power Single Data Source-Alternate I/Q Encoded Symbols (SMAR DG2 only). For a customer platform transmitting alternate I and Q encoded symbols from a data source (single data source-alternate I/Q encoded symbols), the total (I+Q)P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 5-8, where dr is the single data source data rate prior to the rate 1/2 encoder. The Q/I (power) must be equal to 1:1. Refer to Appendix B for further information on this data configuration.

4. Unbalanced Power Single Data Source-Identical Data on the I and Q Channels (DG1 mode 1 and 2). For a customer platform synchronously transmitting identical data on the I and Q channels (single data source-identical data) having unbalanced I and Q channel power division, the stronger power channel P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 5-8 , where dr is the single data source data rate. The weaker power channel P_{rec} need not be consistent with the P_{rec} for a 10^{-5} BER listed in Table 5-8. The Q/I (power) must not exceed 4:1. Refer to Appendix B for further information on this data configuration.

5. Dual Data Sources (DG1 and SMAR DG2). For a customer platform transmitting independent data on the I and Q channels (dual data sources), each channel's P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 5-8, where dr is that channel's data rate. Refer to Appendix B for further information on this data configuration.

6. Single Data Source with Single Data Channel (DG1 modes 1 and 2 and SMAR DG2). For a customer platform transmitting one channel the P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 5-8, where dr is the channel data rate. Refer to Appendix B for further information on this data configuration.

c. Customer Degradations. Further reductions in the TDRSS MA return service performance identified in Table 5-8 can occur. The TDRSS MA return service will also be degraded due to RFI (refer to Appendix G). The TDRSS MA return services and tracking services will be provided without degradation for user customer platform transmitted signal characteristics within the constraints specified in Table 5-11. Customer platform parameters exceeding these constraints can also degrade TDRSS MA return service performance. Refer to paragraph 3.5 for guidelines if the constraints in this paragraph cannot be met. Definitions of user customer platform constraints are given in Appendix E.

d. Multipath. The WSC will provide lockup and interference protection from multipath signals reflected from the Earth.

e. Periodic Convolutional Interleaving. At baud rates above 300 kbps, symbol interleaving of the customer platform transmission is recommended for DG1 mode 3 and DG2 signals. Biphase symbol formats are not allowed with PCI. When interleaving is not employed at baud rates above 300 kbps, S-band performance may not be guaranteed. Deinterleaving is not supported for baud rates $\leq$ 300 kbps. The functional description of the (30,116) periodic convolutional interleaving of either rate 1/2 or rate 1/3 convolutional encoder symbols, which will be used when identified in the SHO, is defined in Appendix F.

5.3.3.3 Signal Tracking

TDRSS provides MA return signal tracking (carrier, PN, symbol synchronization, convolutional deinterleaver synchronization, Viterbi decoder synchronization) for both powered (SMAR only) and non-powered flight dynamics. During a customer MA return service support period, loss-of-lock (carrier, symbol synchronization, and Viterbi decoder) indications appear in the periodically updated User Performance Data (UPD) (every 5 seconds).

a. Non-powered Flight Dynamics. For all valid return service signals operating under non-powered flight dynamics, the MA return service shall maintain signal tracking for the following conditions:

    1. Cycle Slips. The mean-time-between-cycle slip in the WSC carrier tracking loop for each TDRSS MA return service is 90 minutes, minimum. This value applies at carrier tracking threshold, which is 3 dB less than the minimum P_{rec} required for BER, and increases exponentially as a function of linear dB increases in P_{rec}. Cycle slips may result in channel and/or data polarity reversal. WSC can correct for these reversals under the same conditions as WSC can resolve channel and/or data polarity ambiguity as discussed in Appendix B. The time for the WSC to recover from a cycle slip will be consistent with the time required for the WSC receiver to detect and automatically reacquire the signal.

    2. Bit Slippage. For each TDRSS MA return service operating with a minimum P_{rec} required consistent with the P_{rec} for BER and data transition densities greater than 40% for NRZ symbols or any transition density for biphase symbols, the minimum mean time between slips caused by a cycle slip in the WSC symbol clock recovery loop is either

90 minutes or 10^{10} symbol periods, whichever is greater. For an MA return service operating with 1 dB more than the minimum P_{rec} required for BER, and NRZ symbol transition densities between 25% and 40%, the minimum mean time between slips is either 90 minutes or 10^{10} symbol periods, whichever is greater.

3. Loss of Symbol Synchronization. For each TDRSS MA return service with data transition densities greater than 40% for NRZ symbols and any transition density for biphase symbols, the WSC symbol synchronization loop will not unlock for a P_{rec} that is 3 dB less than the minimum P_{rec} required for BER. For NRZ symbol transition densities between 25% and 40%, the WSC symbol synchronizer loop will not unlock for a P_{rec} that is 2 dB less than the minimum P_{rec} required for BER. In both cases, BER performance will be degraded when the P_{rec} is less than the minimum P_{rec} required for BER.

b. Powered Flight Dynamics (SMAR only). TDRSS will provide signal tracking with a probability of more than 0.99 over 90 minutes for a customer with powered flight dynamics and an ephemeris uncertainty as defined in Table 5-8. This value applies at the carrier tracking threshold. For F8 (cold), F9, F10, the carrier tracking threshold for DG1 signals is a minimum P_{rec} of -193.5 dBW for LEOFOV, -192.2 dBW for PFOV, or the minimum P_{rec} for BER, whichever is greater. For F8 (hot), the carrier tracking threshold for DG1 signals is a minimum P_{rec} of –190.2 dBW for LEOFOV, -188.8 dBW for PFOV, or the minimum P_{rec} for BER, whichever is greater. For F8 (cold), F9, F10, the carrier tracking threshold for DG2 signals is a minimum P_{rec} of –187.4 dBW for LEOFOV, -186.1 dBW for PFOV, or the minimum P_{rec} for BER, whichever is greater. For F8 (hot), the carrier tracking threshold for DG2 signals is a minimum P_{rec} of –184.1 dBW for LEOFOV, -182.7 dBW for PFOV, or the minimum P_{rec} for BER, whichever is greater.

NOTE

The F8 spacecraft has some SMA return G/T performance variations due to an MA element array and sunshield proximity problem. The G/T varies based upon the normal daily TDRS diurnal cycle. The hot periods can be predicted and will occur at regular intervals with a total hot period of less than 12 hours/day. Customers attempting to schedule around hot periods, should reference the Flight Dynamics Facility Products Center web page at http://mmfd.gsfc.nasa.gov/prod_center/pc_frame_page.htm for further information on the daily TDRS-8 diurnal cycle.

5.3.3.4 Reacquisition

While in the PN/carrier tracking state, a loss of lock condition induced by a cycle slip will be automatically detected and a reacquisition will be automatically initiated. For a customer platform that continues to transmit the minimum P_{rec} for acquisition and maintains an ephemeris uncertainty as defined in Table 5-8, the normal total channel reacquisition time for either powered or non-powered flight dynamics will be less than or equal to that for the initial total channel acquisition for non-powered flight dynamics, with a probability of at least 0.99. If lock is not achieved within 10 seconds of loss of lock, an acquisition failure notification will be sent to the MOC and WSC will reinitiate the initial service acquisition process. TDRSS MA return service does not support acquisition of customers with powered flight dynamics. Upon receipt of the loss-of-lock indications in the UPD, the customer MOC may request a TDRSS MA return service reacquisition GCMR (refer to section 10). It is recommended that the customer MOC delay initiation of the GCMR for at least 35 seconds after initial receipt of the loss-of-lock indications in the UPD.

5.3.3.5 Additional Service Restrictions

a. Sun Interference. The TDRSS MA return service performance will not be guaranteed when the center of the sun is within 3 degrees (MAR) or 4 degrees (SMAR) of the TDRS MA receiving antenna boresight; however, this sun interference checking is a customer MOC responsibility. Additionally, the TDRSS MA return service performance will not be guaranteed when the center of the sun is within 1 degree of the boresight of the WSC receiving antenna supporting the TDRS.

b. Frequency and Polarization. The TDRSS MA return service requires a customer platform to transmit at 2287.5 MHz with LHC polarization (refer to Appendix D for power level restrictions into the 2290-2300 MHz band).

5.3.4 Real-Time Configuration Changes

Changes to the operating conditions or configuration of a TDRSS MA return service during a scheduled service support period are initiated by a GCMR from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the GCMR at the WSC. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning WSC response times for GCMRs is provided in section 10. Table 5-10 lists the MA return service real-time configuration changes and their effects on the return service.

Table 5-10. MA Return Service Real-Time Configuration Changes

Real-Time Configuration Changes	GCMR	OPM	Return Service Interruption
Return Service Reacquisition	98/03	OPM 03	Yes
Noncoherent Expanded User Spacecraft Frequency Uncertainty	98/07	OPM 07	No
Channel Data Rate	98/04	OPM 03	No
Noncoherent Transmit Frequency	98/04	OPM 03	Yes
Redefinition of minimum customer EIRP	98/04	OPM 03	Yes
Redefinition of maximum customer EIRP	98/04	OPM 03	No
I/Q Power Ratio	98/04	OPM 03	Yes
Channel Data Format	98/04	OPM 03	No
Channel Data Bit Jitter	98/04	OPM 03	No
DG1 Mode	98/04	OPM 03	Yes
Data Group (SMAR only)	98/04	OPM 03	Yes
DG2 Coherency (coherent or noncoherent) (SMAR only)	98/04	OPM 03	Yes
Periodic Convolutional Interleaving (SMAR only)	98/04	OPM 03	No
DG2 Carrier Modulation (SMAR only)	98/04	OPM 03	Yes
Data Source/Channel Configuration	98/04	OPM 03	Yes
G_2 inversion	98/04	OPM 03	No
Frame Length	98/04	OPM 03	No
Frame Sync Word Length	98/04	OPM 03	No
Frame Sync Word Bit Pattern	98/04	OPM 03	No
Sync Strategy Parameters	98/04	OPM 03	No
Note: Items that are indicated to cause return service interruption will cause the WSC receiver to discontinue signal tracking and attempt to reacquire the return service signal after the appropriate reconfiguration. Additionally, any reconfigurations to the forward that cause forward link interruption will also cause return interruption for coherent return links. Any other reconfigurations of the WSC may momentarily affect signal tracking.			

5.3.5 Acquisition Scenarios

The following acquisition scenarios identify only the technical aspects of TDRSS MA return service signal acquisition by WSC and do not include operational procedures related to acquisition. Acquisition is dependent upon the customer providing an ephemeris with a maximum uncertainty as defined in Table 5-8.

a. Coherent Modes (DG1 Mode 1, DG1 Mode 3 (SMAR only), and DG2 Coherent (SMAR only))

   1. For optimal TDRSS performance, all coherent services should have the TDRSS forward and return services starting at the same time. If operational considerations require starting the TDRSS forward service before the return service, no reconfigurations of the forward service can be sent within 30 seconds of the start of the return service. A forward link sweep request OPM cannot be sent within 150 seconds of the start of the return service.

   2. The customer platform P_{rec} must be compatible with the minimum P_{rec} required for BER and the other TDRSS MA return service signal parameters listed in Table 5-8.

   3. The WSC will adaptively point the spatially formed TDRSS MA antenna beam in the direction of the customer platform.

   4. At the service start time specified by the SHO, the WSC will begin the search for the customer platform signal based upon predicted range and Doppler. The WSC corrects the received customer platform signal for Doppler to allow for WSC implementation of receivers with narrow acquisition and tracking bandwidths. The Doppler correction used by WSC is either one-way (Forward Doppler compensation enabled) or two-way (Forward Doppler compensation inhibited). For coherent operation, the Doppler correction is based upon the forward service frequency.

   5. After the forward service has been acquired, the WSC will acquire the customer platform signal (PN code (applicable to DG1 only) and carrier) within the time listed in Table 5-8. Return service will be achieved at the WSC receiver output within the total channel acquisition time limits listed in Table 5-8, which includes WSC symbol, deinterleaver (if applicable), and Viterbi decoder synchronization.

b. Noncoherent (DG1 Mode 2 and DG2 Noncoherent (SMAR only))

   1. This mode of customer platform operation does not require that a TDRSS (MA or SSA) forward service signal be received by the customer platform. However, the customer platform transmitter must be commanded to turn on when noncoherent transmissions are desired, either by stored commands, on-board configuration settings, or direct commands from its customer MOC.

2. The customer platform P_{rec} must be compatible with the minimum P_{rec} required for BER and the other TDRSS MA return service signal parameters listed in Table 5-8.

3. The WSC will adaptively point the spatially formed TDRS MA antenna beam in the direction of the customer platform.

4. At the service start time specified by the SHO, the WSC will begin the search for the customer platform signal based upon predicted Doppler. The WSC corrects the received customer platform signal for Doppler to allow for WSC implementation of receivers with narrow acquisition and tracking bandwidths. The Doppler correction used by WSC is one-way and based on the customer platform transmission frequency stated in the SHO and any subsequent OPMs.

5. The WSC will acquire the customer platform signal (PN code (applicable to DG1 only) and carrier) within the time limits listed in Table 5-8. Return service will be achieved at the WSC receiver output within the total acquisition time limits listed in Table 5-8, which includes WSC symbol and Viterbi decoder synchronization.

c. <u>DG1 Mode Transitions</u>.

1. <u>DG1 Mode 2 to DG1 Mode 1 Transition</u>. A TDRSS (MA or SSA) forward service must be scheduled to be established prior to customer MOC transmission of the GCMR to reconfigure the TDRSS for DG1 mode 1 operations (refer to paragraph 5.3.5.a(1)).

2. <u>DG1 Mode 1 to DG1 Mode 2 Transitions</u>. When the customer platform switches to the noncoherent mode (DG1 mode 2), customer platform return service signal parameters (e.g., carrier and channel PN codes) are changed causing the WSC to drop TDRSS MA return service signal lock. Customer platform transponders designed to automatically switch from a coherent transponder mode to a noncoherent mode when the TDRSS SSA/MA forward service signal is lost will result in WSC loss of MA return service signal lock. Reconfiguration and reacquisition by the WSC is required and must be initiated by a GCMR from the customer MOC.

NOTE

Failure to observe these conventions may result in WSC rejection of reconfiguration messages, excessive acquisition times, and unnecessary loss of customer platform return service data.

d. <u>DG2 Mode Transitions</u>.

1. <u>DG2 noncoherent to DG2 coherent Transitions</u>. A TDRSS (MA or SSA) forward service must be scheduled to be established prior to customer MOC transmission of the GCMR to reconfigure the TDRSS for DG2 coherent operations (refer to paragraph 5.3.5.a.(1)).

2. DG2 coherent to DG2 noncoherent Transitions. When the customer platform switches to the noncoherent mode, the resulting customer transmit frequency offset will probably cause the WSC to drop TDRSS MA return service signal lock when the switch is made. If return service signal lock is lost, reconfiguration and reacquisition by the WSC is required and must be initiated by a GCMR from the customer MOC.

NOTE

Failure to observe these conventions may result in WSC rejection of reconfiguration messages, excessive acquisition times, and unnecessary loss of customer platform return service data.

Table 5-11. TDRSS MA Return Service Customer Platform Signal Constraints

Parameters (Notes 1 and 2)	**Description** (Notes 1 and 2)
Minimum channel symbol transition density (Note 3)	≥128 randomly distributed symbol transitions within any sequence of 512 symbols
Consecutive channel symbols without a symbol transition	≤ 64 symbols
Symbol asymmetry (peak)	≤ ± 3 percent
Symbol rise time (90 percent of initial state to 90 percent of final state)	≤ 5 percent of symbol duration but > 35 nsec
Symbol jitter and jitter rate	≤ 0.1 percent
Phase imbalance	
DG1 modes 1 and 2	≤ ± 5 degrees
DG1 mode 3 (applicable to SMA only)	
Q channel baud rate ≤ 1.024 Msps	≤ ± 5 degrees
Q channel baud rate > 1.024 Msps	≤ ± 3 degrees
DG2 (applicable to SMA only)	
BPSK	
Baud rate ≤ 1.024 Msps	≤ ± 9 degrees
Baud rate > 1.024 Msps	≤ ± 3 degrees
QPSK	
Baud rate per channel ≤ 1.024 Msps	≤ ± 5 degrees
Baud rate per channel > 1.024 Msps	≤ ± 3 degrees
Gain imbalance	
DG1 modes 1 and 2	≤ ± 0.50 dB
DG1 mode 3 (applicable to SMA only)	
Q channel baud rate ≤ 1.024 Msps	≤ ± 0.50 dB
Q channel baud rate > 1.024 Msps	≤ ± 0.25 dB
DG2 (applicable to SMA only)	
BPSK	
Baud rate ≤ 1.024 Msps	≤ ± 1.0 dB
Baud rate > 1.024 Msps	≤ ± 0.25 dB
QPSK	
Baud rate per channel ≤ 1.024 Msps	≤ ± 0.50 dB
Baud rate per channel > 1.024 Msps	≤ ± 0.25 dB

Table 5-11. TDRSS MA Return Service Customer Platform Signal Constraints (Cont'd)

Parameters (Notes 1 and 2)	**Description** (Notes 1 and 2)
Phase nonlinearity (applies for all types of phase nonlinearities) (peak)	
DG1 modes 1 and 2	≤ 4 degrees over ±2.1 MHz
DG1 mode 3 (applicable to SMA only)	
Q channel baud rate ≤ 1.024 Msps	≤ 4 degrees over ±2.1 MHz
Q channel baud rate > 1.024 Msps	≤ 3 degrees over ±2.1 MHz
DG2 (applicable to SMA only)	
Baud rate per channel ≤ 1.024 Msps	≤ 4 degrees over ±1.0 MHz
Baud rate per channel > 1.024 Msps	≤ 3 degrees over ±2.1 MHz
Gain flatness (peak)	
DG1 modes 1 and 2	≤ 0.4 dB over ±2.1 MHz
DG1 mode 3 (applicable to SMA only)	
Q channel baud rate ≤ 1.024 Msps	≤ 0.4 dB over ±2.1 MHz
Q channel baud rate > 1.024 Msps	≤ 0.3 dB over ±2.1 MHz
DG2 (applicable to SMA only)	
Baud rate per channel ≤ 1.024 Msps	≤ 0.4 dB over ±1.0 MHz
Baud rate per channel > 1.024 Msps	≤ 0.3 dB over ±2.1 MHz
Gain slope (peak)	
DG1 modes 1 and 2	Not specified
DG1 mode 3 (applicable to SMA only)	
Q channel baud rate ≤ 1.024 Msps	Not specified
Q channel baud rate > 1.024 Msps	≤ 0.1 dB/MHz over ±2.1 MHz
DG2 (applicable to SMA only)	
Baud rate per channel ≤ 1.024 Msps	Not specified
Baud rate per channel > 1.024 Msps	≤ 0.1 dB/MHz over ±2.1 MHz
AM/PM	
DG1 modes 1 and 2	≤ 15 degrees/dB
DG1 mode 3 (applicable to SMA only)	
Q channel baud rate ≤ 1.024 Msps	≤ 15 degrees/dB
Q channel baud rate > 1.024 Msps	≤ 12 degrees/dB

Table 5-11. TDRSS MA Return Service Customer Platform Signal Constraints (Cont'd)

Parameters (Notes 1 and 2)	**Description** (Notes 1 and 2)
AM/PM (cont'd):	
DG2 (applicable to SMA only)	
Baud rate per channel $\leq$ 1.024 Msps	$\leq$ 15 degrees/dB
Baud rate per channel > 1.024 Msps	$\leq$ 12 degrees/dB
Noncoherent frequency stability (peak) (Notes 4, 5)	
$\pm$700 Hz customer oscillator frequency uncertainty	
1-sec average time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 1 \times 10^{-7}$
48-hr observation time	$\leq 3 \times 10^{-7}$
$\pm$ 3 kHz customer oscillator frequency uncertainty	
1-sec average time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 4.3 \times 10^{-7}$
48-hr observation time	$\leq 1.29 \times 10^{-6}$
$\pm$ 35 kHz customer oscillator frequency uncertainty	
1-sec average time	
Baud rate per channel $\leq$ 12.5 ksps	$\leq 7.37 \times 10^{-9}$
Baud rate per channel > 12.5 ksps	$\leq 26 \times 10^{-9}$
5-hr observation time	$\leq 3.77 \times 10^{-6}$
48-hr observation time	$\leq 11.3 \times 10^{-6}$
Incidental AM (peak):	
At frequencies $\geq$10 Hz for data rates <1 kbps; at frequencies >100 Hz for data rates ≥1 kbps	$\leq$ 5 percent
Spurious PM (rms)	
DG1	$\leq$ 2 degrees
DG2 (applicable to SMA only)	
BPSK	$\leq$ 2 degrees
QPSK	
I/Q = 4:1	$\leq$ 2 degrees
I/Q = 1:1	$\leq$ 1 degree

Table 5-11. TDRSS MA Return Service Customer Platform Signal Constraints (Cont'd)

Parameters (Notes 1 and 2)	**Description** (Notes 1 and 2)
Minimum 3-dB bandwidth prior to power amplifier	
DG1	≥ 4.5 MHz or two times maximum baud rate, whichever is larger
DG2 (applicable to SMA only)	≥ 2 times maximum channel baud rate
Phase noise (rms) (Note 6)	
DG1 Mode 1	
Doppler Tracking Required	
All baud rates	
1 Hz – 10 Hz	≤1.0° rms
10 Hz – 1 kHz	≤1.0° rms
1 kHz – 3 MHz	≤1.5° rms
Doppler Tracking NOT Required (Note 7)	
Channel baud rate < 18 ksps	
1 Hz – 10 Hz	≤1.8° rms
10 Hz – 1 kHz	≤1.5° rms
1 kHz – 3 MHz	≤1.5° rms
Channel baud rate ≥ 18 ksps	
1 Hz – 10 Hz	≤ 25.0° rms
10 Hz – 1 kHz	≤ 2.5° rms
1 kHz – 3 MHz	≤ 2.0° rms
DG1 Mode 2	
Doppler Tracking Required	
All baud rates	
1 Hz – 10 Hz	≤ 2.0° rms
10 Hz – 100 Hz	≤ 1.0° rms
100 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 3 MHz	≤ 2.0° rms

Table 5-11. TDRSS MA Return Service Customer Platform Signal Constraints (Cont'd)

Parameters (Notes 1 and 2)	**Description** (Notes 1 and 2)
Phase noise (rms) (Note 6)	
DG1 Mode 2 (cont'd)	
Doppler Tracking NOT Required (Note 7)	
Channel baud rate < 4.5 ksps	
1 Hz – 10 Hz	≤ 3.8° rms
10 Hz – 100 Hz	≤ 1.8° rms
100 Hz – 1 kHz	≤ 1.4° rms
1 kHz – 3 MHz	≤ 1.4° rms
Channel baud rate ≥ 4.5 ksps	
1 Hz – 10 Hz	≤ 22.0° rms
10 Hz – 100 Hz	≤ 2.2° rms
100 Hz – 1 kHz	≤ 1.4° rms
1 kHz – 3 MHz	≤ 1.4° rms
DG1 Mode 3 (applicable to SMA only)	
Doppler Tracking Required	
All baud rates	
1 Hz – 10 Hz	≤ 1.0° rms
10 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 6 MHz	≤ 1.5° rms
Doppler Tracking NOT Required (Note 7)	
Channel baud rate < 222.5 ksps	
1 Hz – 10 Hz	≤ 4.0° rms
10 Hz – 1 kHz	≤ 2.8° rms
1 kHz – 6 MHz	≤ 1.4° rms
Channel baud rate ≥ 222.5 ksps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 1 kHz	≤ 5.5° rms
1 kHz – 6 MHz	≤ 1.8° rms
DG2 Coherent (applicable to SMA only)	
Doppler Tracking Required	
All baud rates	
1 Hz – 10 Hz	≤1.0° rms
10 Hz – 1 kHz	≤1.0° rms
1 kHz – 3 MHz	≤2.0° rms

Table 5-11. TDRSS MA Return Service Customer Platform Signal Constraints (Cont'd)

Parameters (Notes 1 and 2)	**Description** (Notes 1 and 2)
Phase noise (rms) (Note 6) (cont'd)	
DG2 Coherent (applicable to SMA only) (cont'd)	
Doppler Tracking NOT Required (Note 7)	
Channel baud rate < 18 ksps	
1 Hz – 10 Hz	≤3.8° rms
10 Hz – 1 kHz	≤2.3° rms
1 kHz – 3 MHz	≤2.0° rms
Channel baud rate between 18 ksps and 1.024 Msps	
1 Hz – 10 Hz	≤25.0° rms
10 Hz – 1 kHz	≤2.5° rms
1 kHz – 3 MHz	≤2.0° rms
Channel baud rate > 1.024 Msps	
1 Hz – 10 Hz	≤5.0° rms
10 Hz – 1 kHz	≤1.0° rms
1 kHz – 3 MHz	≤0.5° rms
DG2 Noncoherent (applicable to SMA only)	
Doppler Tracking Required	
All baud rates	
1 Hz – 10 Hz	≤ 2.0° rms
10 Hz – 100 Hz	≤ 1.0° rms
100 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 3 MHz	≤ 2.0° rms
Doppler Tracking NOT Required (Note 7)	
Channel baud rate < 12.5 ksps	
1 Hz – 10 Hz	≤ 5.0° rms
10 Hz – 100 Hz	≤ 1.0° rms
100 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 3 MHz	≤ 2.0° rms
Channel baud rate between 12.5 ksps and 1.024 Msps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 100 Hz	≤ 5.5° rms
100 Hz – 1 kHz	≤ 2.4° rms
1 kHz – 3 MHz	≤ 2.4° rms

Table 5-11. TDRSS MA Return Service Customer Platform Signal Constraints (Cont'd)

Parameters (Notes 1 and 2)	**Description** (Notes 1 and 2)
Phase noise (rms) (Note 6) (cont'd)	
DG2 Noncoherent (applicable to SMA only) (cont'd)	
Doppler Tracking NOT Required (Note 7)	
Channel baud rate > 1.024 Msps	
1 Hz – 10 Hz	≤ 10.0° rms
10 Hz – 100 Hz	≤ 1.5° rms
100 Hz – 1 kHz	≤ 0.5° rms
1 kHz – 3 MHz	≤ 0.5° rms
In-band spurious outputs, where in-band is twice the maximum channel baud rate	
DG1 modes 1 and 2	≥ 23 dBc
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≥ 23 dBc
Q channel baud rate > 1.024 Msps	≥ 30 dBc
DG2	
Baud rate per channel ≤ 1.024 Msps	≥ 23 dBc
Baud rate per channel > 1.024 Msps	≥ 30 dBc
Out-of-band emissions	See Appendix D for allowable limits on out-of-band emissions, including spurs
I/Q symbol skew (relative to requirements of I/Q data synchronization where appropriate) (peak)	≤ 3 percent
I/Q PN chip skew (relative to 0.5 chip)	≤ 0.01 chip
PN chip rate (peak), DG1 mode 2 (relative to absolute coherence with carrier rate)	≤ 0.01 chips/sec at PN code chip rate
PN power suppression (noncoherent and coherent)	≤ 0.3 dB
Customer Antenna-Induced AM	≤ 3 dB
Customer Antenna-Induced PM	≤ 10 degrees
Data rate tolerance	≤ ±0.1 percent
I/Q power ratio tolerance	≤ ±0.4 dB
Permissible P_{rec} variation without reconfiguration GCMR from customer MOC) (Note 8)	≤12 dB
Permissible rate of P_{rec} variation	≤10 dB/sec
Maximum P_{rec}	
For support through F1-F7	-161.2 dBW
For support through F8-F10	-149 dBW

Table 5-11. TDRSS MA Return Service Customer Platform Signal Constraints (Cont'd)

Notes:
1. The definitions and descriptions of the customer constraints are provided in Appendix E.
2. When a constraint value is listed for a baud rate range and data is transmitted on both channels, the maximum baud rate of the 2 channels should be used to determine the constraint value applicable.
3. It is recommended that customers use G_2 inversion to increase symbol transition density. Additionally, biphase symbol formatting increases symbol transition density.
4. The frequency stability requirements are valid at any constant temperature (±0.5° C) in the range expected during the mission. At a minimum, a temperature range of -10° C to +55° C shall be considered.
5. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of ± 700 Hz. If a customer cannot accurately define their transmit frequency to within ± 700 Hz, a customer can request a reconfiguration which would expand the oscillator frequency search to ± 3 kHz for DG1 and SQPSK DG2 configurations and ± 35 kHz for BPSK and QPSK DG2 configurations after the start of service.
6. Derivation of the phase noise requirements involved making assumptions about the distribution of the phase noise power in each frequency region. Since no phase noise PSD will exactly match the phase noise power distribution assumed for this derivation, phase noise PSDs which are close to violating the phase noise limits or phase noise PSDs which violate the phase noise limits should be evaluated on a case-by-case basis to determine their acceptability.
7. Applicable for customers that have no Doppler tracking requirement or can tolerate a total Doppler tracking error greater than 0.2 rad/sec.
8. The minimum SHO EIRP should reflect the minimum P_{rec} expected over the service period, where the P_{rec} can exceed this minimum by no more than 12 dB. An actual customer P_{rec} value that is 12 dB greater than the minimum may cause false PN lock or nonacquisition.

Section 6. SSA Telecommunications Services

6.1 General

6.1.1 Available Services

TDRSS SSA services include forward and return telecommunications services, and tracking services. Tracking services are discussed in Section 9. This section focuses on the RF interface between the TDRS and the customer platform. This interface is characterized by the technical requirements imposed and the operational capabilities provided by the TDRSS. The operational interfaces are described in further detail in Section 10. Data interfaces between the customer MOC and the SN are described in paragraph 3.6.

NOTE

> The DSMC issues Network Advisory Messages (NAMS) to provide up-to-date information on network conditions and constraints. These messages are accessible via the DSMC active NAMS web site at http://128.183.140.27/nam/wnserch.htm. At the time of publication of this revision, the TDRS F9 and F10 spacecraft are not operational. Prior to the next revision of this document, the GSFC MSP will use the NAMs as a means of letting customers know of any performance constraints associated with these spacecraft as well as any of the other TDRS.

6.1.2 Interface Definition

The RF interface between the TDRS and a customer platform is defined in terms of signal parameters, RF characteristics, and field of view.

a. The RF interface for forward service represents the transmission by a TDRS of an appropriately modulated signal at or greater than a minimum signal EIRP in the direction of the desired customer platform. SSA forward (SSAF) service is discussed in paragraph 6.2.

b. The RF interface for return service defines a minimum received power (P_{rec}) at the TDRS antenna input for a specified data quality at the WSC receiver output. SSA return (SSAR) service is discussed in paragraph 6.3.

NOTE

> The SSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.

6.1.3 Customer Acquisition Requirements

Acquisition and reacquisition by the customer platform of the TDRS transmitted signal requires prediction by the customer MOC of the customer platform receive frequency over various projected time periods. Similarly, acquisition and reacquisition by the WSC of the customer platform signal requires prediction by the customer MOC of the customer platform transmitter frequency over various projected time periods. The frequency predictions are ultimately incorporated in the Schedule Order (SHO) as customer platform frequencies for the specific service support periods. Refer to section 9 for additional information on TDRSS tracking services that can assist customers to predict their local oscillator frequencies.

6.1.4 TDRSS Acquisition Support to Customers

For each scheduled TDRSS service support period, the customer requirements for signal acquisition/reacquisition and the TDRSS capabilities to aid acquisition/reacquisition are as follows:

a. Customer Epoch Uncertainty. The maximum epoch uncertainty of the customer platform ephemeris supplied to the TDRSS should be ±9 seconds for the SSA primary field of view (PFOV) and ±7.8 seconds for the SSA F8-F10 extended elliptical field of view (EEFOV) as defined in Table 6-3 for SSA forward (SSAF) and Table 6-9 for SSA return (SSAR) services.

b. Customer Frequency Uncertainty. The customer MOC must know the operating frequency of the customer platform to within ±700 Hz.

c. Forward Frequency Sweep. After the start of the forward link service, the TDRSS has a forward service frequency sweep capability of ±3 kHz for the phase-shift key (PSK) modulation services and a sweep capability of up to ±600 kHz for the phase modulation (PM) services.

d. Noncoherent Return Expanded Frequency Search. After the start of the noncoherent return link service, the TDRSS has a return service expanded frequency search capability to accommodate a customer platform's operating frequency uncertainty of up to ±3 kHz for the DG1 and SQPSK DG2 services and up to ±35 kHz for the BPSK and non-staggered QPSK DG2 services.

6.2 SSA Forward Services

6.2.1 General

The characteristics of the data provided to the WSC interface and the RF signals provided by the TDRS to the customer platform during TDRSS SSA forward services are described in paragraphs 6.2.2 through 6.2.6. This discussion assumes that an appropriate forward service has been scheduled and a data signal is present at the WSC interface.

For SSA, this document refers to two general modulation categories as follows:

a. PSK modulation: refer to paragraph 6.2.2 for specific signal parameters

b. Phase modulation (PM): refer to paragraph 6.2.3 for specific signal parameters

6.2.2 PSK Signal Parameters

The TDRSS SSA forward PSK signal parameters are defined in Table 6-1. The center frequency, f_o, of the customer platform receiver must be defined by the customer MOC in its service specification code for TDRSS SSA forward service (refer to paragraph 10.2.2). A description of the features inherent in the QPSK and BPSK signal parameters listed in Table 6-1 are discussed in paragraphs 6.2.2.1 and 6.2.2.2, respectively.

6.2.2.1 QPSK Signal Parameters

a. Unbalanced QPSK Modulation. The I channel is used to transmit the customer command data and is referred to as the command channel. The Q channel transmits a range signal and is referred to as the range channel. The command channel/range channel power ratio for QPSK forward service signals is +10 dB. This unbalanced QPSK modulation minimizes the power in the range channel to a level adequate for customer platform range channel acquisition and tracking. This feature increases the power in the command channel by 2.6 dB over that for balanced QPSK modulation without increasing customer platform receiver complexity, increasing customer platform command channel acquisition time, or decreasing TDRSS range tracking accuracy.

b. Spread Spectrum. TDRSS SSA forward services with data rates equal to and below 300 kbps should incorporate spread spectrum modulation techniques to satisfy flux density restrictions imposed on the TDRSS forward services by the NTIA. This modulation scheme includes separate but simultaneous command and range channels. The command channel includes a rapidly acquirable PN code and contains the forward service data. The range channel is acquired separately and contains a PN code which satisfies the range ambiguity resolution requirements. The length of the command channel PN code is 2^{10}-1, where the length of the range channel PN code is 256 times the command channel PN code length. The customer platform command channel acquisition can precede customer platform range channel acquisition; this feature permits rapid acquisition of the range channel by limiting the range channel PN code search to only 256 chip positions while the range channel PN code itself contains 261,888 chips. The PN code chip rate is coherently related to the TDRS transmit frequency in all cases. This feature permits the customer platform receiver to use the receiver PN code clock to predict the received carrier frequency, thereby minimizing receiver complexity and reducing acquisition time. 451-PN CODE-SNIP defines all the salient characteristics for the forward range and command channel PN code libraries. The agency Spectrum Manager responsible for PN code assignments will allocate a customer platform-unique PN code assignment from these libraries. The GSFC Spectrum Manager is responsible for NASA PN code assignments.

Table 6-1. TDRSS SSA Forward PSK Service Signal Parameters

Parameter	Description
TDRS transmit carrier frequency (Hz)	F
Carrier frequency arriving at customer platform (Hz) (note 1)	F_R
Carrier frequency sweep (note 4)	$\pm$3 kHz
Carrier frequency sweep duration (note 4)	120 seconds
QPSK (PN modulation enabled)	
$\frac{\text{Command channel radiated power}}{\text{Range channel radiated power}}$	+10 dB
QPSK Command Channel	
Carrier frequency (Hz)	Transmit carrier frequency (F)
PN code modulation	PSK, $\pm\pi/2$ radians
Carrier suppression	30 dB minimum
PN code length (chips)	$2^{10} - 1$
PN code epoch reference	Refer to 451-PN CODE-SNIP
PN code family	Gold codes
PN code chip rate (chips/sec)	$\frac{31}{221 \times 96} \times F$
Data modulation	Modulo-2 added asynchronously to PN code
Data format (note 2)	Not Applicable
Data rate restrictions (note 2)	0.1 - 300 kbps
QPSK Range Channel	
Carrier	Command channel carrier frequency delayed $\pi/2$ radians
PN code modulation	PSK $\pm$ $\pi/2$ radians
Carrier suppression	30 dB minimum
PN code chip rate	Synchronized to command channel PN code chip rate
PN code length (chips)	$(2^{10} - 1) \times 256$
PN code epoch reference	All 1's condition synchronized to the command channel PN code epoch.
PN code family	Truncated 18-state shift register sequences

Table 6-1. TDRSS SSA Forward PSK Service Signal Parameters (cont'd)

Parameter	Description
BPSK (PN modulation disabled)	
Carrier frequency (Hz)	Transmit carrier frequency (F)
Data modulation	PSK, $\pm\pi/2$ radians
Carrier suppression	30 dB minimum
Data format (note 2)	Not Applicable
Data rate restrictions (notes 2, 3)	300 kbps - 7 Mbps

Notes:

1. The center frequency, fo, of the customer platform receiver must be defined by the customer MOC in its service specification code to an integral multiple of 10 Hz. Doppler compensation will be available for $\dot{R} \leq 12$ km/sec. During periods of Doppler compensation, $F_R = f_o \pm E$ Hz; where f_o = nominal center frequency of customer platform receiver as defined by the customer MOC and $E = (70 \times \ddot{R}) \pm C$; $\ddot{R} \leq 50$ m/sec^2 and C = 10 Hz. During periods of Doppler compensation inhibit, WSC will round-off the customer receive frequency contained in the SHO to the nearest multiple of 221 Hz, which will result in an additional frequency error of up to 110 Hz. If Doppler compensation is inhibited after the start of the forward service, a transition profile will be initiated to slowly change the frequency from the compensate profile to this integer multiple of 221 Hz.

   Forward service Doppler compensation will not increase the effective frequency rate of change seen at the customer receiver more than 28 Hz/sec relative to the frequency for a Doppler-free carrier.
2. For PSK customers, the forward data rate in this table is the baud rate that will be transmitted by the TDRSS (includes all coding and symbol formatting). For non-WDISC customers, forward data conditioning is transparent to the SN. These transparent operations should be performed by the customer prior to transmission to the SN data interface. Refer to paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities.
3. The SN is capable of supporting BPSK signals at data rates less than 300 kbps; however, its use will be controlled and must be coordinated with the GSFC MSP.
4. After the start of the SSA forward PSK service, if a customer MOC is unable to accurately define fo (the nominal center frequency of the customer platform receiver), the forward service carrier frequency can be swept. The SSA forward service frequency sweep will be initiated by the WSC at fo-3 kHz and linearly swept to f_o +3 kHz in 120 seconds and held at fo+3 kHz thereafter. The SSA forward service frequency sweep does not impact simultaneous WSC Doppler compensation of the SSA forward service carrier and PN code rate (if applicable).

c. Asynchronous Data Modulation. For data rates $\leq$ 300 kbps, the forward service data received at WSC from the NISN data transport system is directly modulo-2 added by WSC to the command channel PN code sequence. The forward service data will be asynchronous with the carrier and the PN code.

NOTE

When the command channel does not contain any actual forward service data, the forward service command channel signal is the command channel PN code sequence.

d. Functional Configurations. A further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in section B.2.2.

e. Doppler Compensation. The TDRSS SSA forward service carrier frequency (F) and the PN chip rate transmitted by a TDRS can optionally be compensated by the WSC for Doppler. When compensated, the carrier, F_R, arrives at the customer platform receiving system within a predictable tolerance (E) of f_o as defined in Table 6-1. This feature minimizes the Doppler resolution requirements of the customer platform receiver and is available continuously to facilitate reacquisition by the customer platform in the event of loss of lock of the TDRSS SSA forward service signal. Customers are encouraged to utilize Doppler compensation at all times. Doppler compensation may be inhibited and the TDRSS will transmit a fixed frequency SSA forward service carrier and PN code chip rate.

6.2.2.2 BPSK Signal Parameters

a. BPSK Modulation. For data rates greater than 300 kbps, there is no PN code modulation and the customer data directly BPSK modulates the carrier by $+\pi/2$ radians.

NOTE

The SN is capable of supporting non-spread BPSK signals at data rates less than 300 kbps; however, its use will be controlled and must be coordinated with the GSFC MSP.

b. Asynchronous Data Modulation. The forward service data will be asynchronous with the carrier.

NOTE

When the command channel does not contain any actual forward service data, the forward service command channel signal is carrier only.

c. Functional Configurations. A further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in section B.2.2.

d. Doppler Compensation. The TDRSS SSA forward service carrier frequency (F) transmitted by a TDRS can optionally be compensated by the WSC for Doppler. When compensated, the carrier, FR, arrives at the customer platform receiving system within a predictable tolerance (E) of f_o as defined in Table 6-1. This feature minimizes the Doppler resolution requirements of the customer platform receiver and is available continuously to facilitate reacquisition by the customer platform in the event of loss of lock of the TDRSS SSA forward service signal. Customers are encouraged to utilize Doppler compensation at all times. Doppler compensation may be inhibited and the TDRSS will transmit a fixed frequency SSA forward service carrier.

6.2.3 Phase Modulation (PM) Signal Parameters

The SN is capable of supporting SSA forward phase modulated signals; however, its use will be controlled and must be coordinated with the GSFC MSP. The TDRSS SSA forward residual carrier phase modulation signal parameters are defined in Table 6-2. The center frequency, f_o, of the customer platform receiver must be defined by the customer MOC in its service specification code for TDRSS SSA forward service (refer to paragraph 10.2.2). The features inherent in the signal parameters listed in Table 6-2 are as follows:

a. Direct Phase Modulation. The forward service data received at WSC from the NISN data transport system directly phase modulates the carrier. The forward service data is asynchronous with the carrier.

NOTE

For the direct data phase modulation scheme, the modulation index can be $\pi/2$ radians.

When the command channel does not contain any actual forward service data, the forward service command channel signal is carrier only unless the customer is utilizing the WSC idle pattern feature.

b. PSK Subcarrier Phase Modulation. The forward service data received at WSC from the NISN data transport system PSK modulates either a sinewave or squarewave subcarrier, which, in turn, phase modulates the carrier. The forward service data rate is synchronous with the subcarrier frequency.

NOTE

When the command channel does not contain any actual forward service data, the forward service command channel signal is an unmodulated subcarrier and residual carrier unless the customer is utilizing the WSC idle pattern feature.

c. Functional Configurations. A further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in Section B.2.3.

Table 6-2. TDRSS SSA Forward Phase Modulation Service Signal Parameters

Parameter	Description	
TDRS transmit carrier frequency (Hz)	F	
Carrier frequency arriving at customer platform (Hz) (note 1)	F_R	
Carrier Frequency Sweep (note 5)	±10 Hz to ±600 kHz	
Carrier Frequency Sweep Duration (note 5)	1 to 120 seconds	
Direct Phase Modulation (note 3)		
Carrier frequency (Hz)	Transmit carrier frequency (F)	
Modulation index	0.2 to 1.5 radians, or $\pi/2$ radians	
Data modulation (note 4)	Data directly phase modulates the carrier	
Data format (note 2)	NRZ-L, -M, -S	Biphase-L, -M, -S
Data rate restrictions (note 2)	0.125 kbps - 1 Mbps	0.125 kbps - 500 kbps
PSK Subcarrier Phase Modulation (note 3)		
Carrier frequency (Hz)	Transmit carrier frequency (F)	
Data modulation (note 4)	Data PSK modulates a subcarrier	
Subcarrier Type	Squarewave or Sinusoidal	
Subcarrier Frequency	2, 4, 8, or 16 kHz	
Carrier modulation	Linearly phase modulated by the subcarrier	
Carrier Modulation index	0.2 to 1.8 radians	
Data format (note 2)	NRZ-L, -M, -S	Biphase-L, -M, -S
Data rate restrictions (note 2 and subject to subcarrier to data rate ratio restrictions below)	0.125 kbps - 8 kbps	0.125 kbps - 4 kbps
Subcarrier to Data Rate Ratio (R)	$R=2^n$, where n=1, …7	$R=2^n$, where n=2, …7

Notes:

1. Doppler compensation will be available for $\dot{R} \leq 12$ km/sec. During periods of Doppler compensation, $F_R = f_o \pm E$ Hz; where f_o = nominal center frequency of customer platform receiver as defined by the customer MOC and $E = (70 \times \ddot{R})$; $\ddot{R} \leq 50$ m/sec^2. During periods of Doppler compensation inhibit, WSC will round-off the customer receive frequency contained in the SHO to the nearest multiple of 221 Hz, which will result in an additional frequency error of up to 110 Hz.

   Forward service Doppler compensation will not increase the effective frequency rate of change seen at the customer receiver more than 28 Hz/sec relative to the frequency for a Doppler-free carrier.

Table 6-2. TDRSS SSA Forward Phase Modulation Service Signal Parameters (cont'd)

Notes (cont'd)
2. For PM customers, the forward data rate in this table is the uncoded data rate that will be transmitted by the TDRSS, where the baud rate transmitted by TDRSS is equal to the data rate for uncoded NRZ formatted signals and two times the data rate for uncoded Biphase formatted signals. The SN supports data conditioning for WDISC and forward link PM customers; these customer signal characteristics should be discussed with the GSFC MSP prior to service to determine if the data conditioning will be done at the user MOC or at the SN. Refer to paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities. 3. The SN is capable of supporting SSA forward PM signals; however, its use will be controlled and must be coordinated with the GSFC MSP. 4. WSC can optionally provide idle pattern. 5. After the start of an SSAF PM service, the carrier frequency will sweep plus and minus the Sweep Range (SR) around the center frequency (CF) in a triangle-wave pattern, sweeping from CF to either extreme in Sweep Duration (SD). At sweep start, all modulation (including subcarrier, when applicable) will be removed. The carrier will sweep from CF to (CF – SR) in SD seconds. The sweep will reverse, sweeping from (CF – SR) to CF in SD seconds; then continue sweeping from CF to (CF + SR), again in SD seconds. The sweep will continue in alternating directions (triangle-wave pattern) until a termination request is received. Upon receipt of the termination request, the sweep will continue until it's next arrival at CF and the frequency profile will continue to follow the Doppler compensated frequency profile (if enabled). At sweep termination, modulation will be applied. The SSAF PM service frequency sweep does not impact simultaneous WSC Doppler compensation of the SSAF service carrier. Figure 6-1 depicts an example PM frequency sweep.

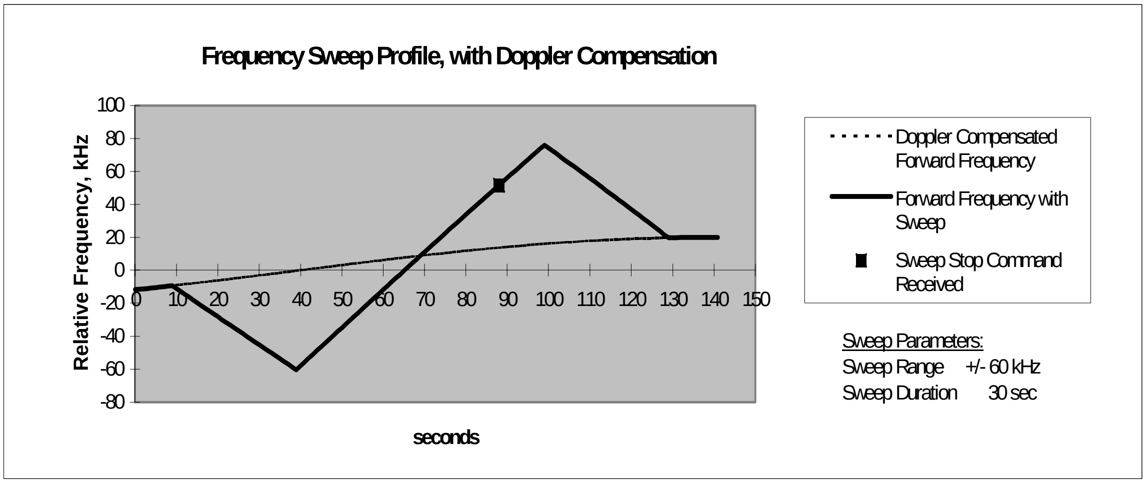


Figure 6-1. <u>Example</u> SSA Forward Phase Modulation Service Frequency Sweep Profile

d. Doppler Compensation. The TDRSS SSA forward service carrier frequency (F) transmitted by a TDRS can optionally be compensated by the WSC for Doppler. When compensated, the carrier, F_R, arrives at the customer platform receiving system within a predictable tolerance (E) of f_o as defined in Table 6-2. This feature minimizes the Doppler resolution requirements of the customer platform receiver and is available continuously to facilitate reacquisition by the customer platform in the event of loss of lock of the TDRSS SSA forward service signal. Customers are encouraged to utilize Doppler compensation at all times. Doppler compensation may be inhibited and the TDRSS will transmit a fixed frequency SSA forward service carrier.

6.2.4 Communications Services

The TDRSS SSA forward service parameters are listed in Table 6-3. Table 6-4 lists their salient characteristics. The definitions for the parameters listed in Table 6-4 are contained in Appendix E.

6.2.5 Real-Time Configuration Changes

Changes to the operating conditions or configuration of a TDRSS SSA forward service during a scheduled service support period are usually initiated by a Ground Control Message Request (GCMR) from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the request at the WSC. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning WSC response times for the GCMRs is provided in Section 10. Table 6-5 lists the SSA forward service real-time configuration changes and their effects on the forward service signal.

6.2.6 Acquisition Scenarios

The following acquisition scenarios identify only the technical aspects of TDRSS SSA forward service signal acquisition by the customer platform and do not include operational procedures related to acquisition:

a. The TDRSS SSA forward service signal does not depend on a customer platform return service.

b. Prior to the start of the TDRSS SSA forward service, the TDRSS SSA antenna will be open-loop pointed in the direction of the customer platform.

Table 6-3. TDRSS SSA Forward Service

Parameter	Description	
Field of view (FOV) (each TDRS)	Primary $\pm$22 degrees east-west $\pm$28 degrees north-south (rectangular)	Extended Elliptical (F8-F10) 24.0 degrees inboard east-west 76.8 degrees outboard east-west $\pm$30.5 degrees north-south
Customer Ephemeris Uncertainty (along the customer orbital track)	$\le \pm$ 9 sec	$\le \pm$ 7.8 sec
TDRS antenna polarization (note 1)	Selectable RHC or LHC	
TDRS antenna axial ratio (maximum)		
Normal or high-power mode	1.5 dB over 3 dB beamwidth	
TDRS signal EIRP (minimum)		
Normal power mode	+43.6 dBW	
High power mode (note 3)	+48.5 dBW	
Transmit frequency (nominal) (note 2)	Selectable receiver frequency 2025.8 MHz to 2117.9 MHz [based on $\frac{221}{240} \times (2200 \text{ to } 2300)$ MHz]	
RF bandwidth (3 dB, minimum)	20 MHz	
Duty factor	100 percent	

Notes:

1. Operational considerations may limit choice of TDRS antenna polarization. The SSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.
2. The customer MOC must include the best estimate of the customer platform receiver center frequency at the start time of each scheduled service support period in its service specification code (refer to paragraph 10.2.2). The TDRSS SSA forward service carrier frequency is then implemented by the WSC to the accuracy of the WSC frequency standard except during Doppler compensation.
3. The TDRSS is capable of transmitting an SSA forward link signal at high power mode; however, its use will be restricted and must be coordinated with the GSFC MSP.

Table 6-4. Salient Characteristics for TDRSS SSA Forward Service

Parameter (Note 1)	**PSK Modulation** (Note 1)		**PM Modulation** (Note 1)	
	QPSK	BPSK		
Command channel radiated power / Range channel radiated power	+10 ±0.5 dB	NA	NA	
Modulation index accuracy	NA		±10% of the modulation index	
			Direct Data	PSK Subcarrier
Subcarrier frequency accuracy	NA		NA	±0.5 Hz
Data transition and subcarrier coherency	NA		NA	Transitions occur at subcarrier zero crossings within ±1 degree
Modulator phase imbalance (peak)	±3 degrees (for each BPSK channel)		NA	NA
Modulator gain imbalance (peak)	±0.25 dB		±0.25 dB	
Relative phase between command and range channels	QPSK 90 ±3 degrees	BPSK NA	NA	
Data asymmetry (peak) (Note 2)	±3 percent		±3 percent	
Data rise time (90 percent of initial state to 90 percent of final state) (Note 2)	≤5 percent of data bit duration		≤5 percent of data bit duration	
Phase nonlinearity (peak)			Direct Data	PSK Subcarrier
For baud rates ≤ 128 kbps	±0.15 radian over ±7 MHz		±0.05 radians over ±90 kHz	±0.05 radians over ±90 kHz
For baud rates > 128 kbps	±0.15 radian over ±7 MHz		±0.25 radians over ±1.5 MHz	NA

Table 6-4. Salient Characteristics for TDRSS SSA Forward Service (cont'd)

Parameter (Note 1)	**PSK Modulation** (Note 1)		**PM Modulation** (Note 1)	
Gain flatness (peak)				
For baud rates ≤ 128 kbps	±0.8 dB over ±7 MHz		±0.8 dB over ±90 kHz	±0.8 dB over ±90 kHz
For baud rates > 128 kbps	±0.8 dB over ±7 MHz		±0.8 dB over ±1.5 MHz	NA
Gain slope (peak)				
For baud rates ≤ 128 kbps	±0.1 dB/MHz		±0.005 dB/kHz over ±90 kHz	±0.005 dB/kHz over ±90 kHz
For baud rates > 128 kbps	±0.1 dB/MHz		±0.75 dB/MHz over ±1.5 MHz	NA
AM/PM	≤10 degrees/dB		≤10 degrees/dB	
PN chip jitter (rms) (including effects of Doppler compensation)	<u>QPSK</u> ≤1 degree	<u>BPSK</u> NA	NA	
Data bit jitter (peak) (Note 2)	≤1 percent		≤1 percent	
Spurious PM (rms)	≤1 degree		≤1 degree	
In-band spurious outputs	≥27 dBc		≥27 dBc	
Incidental AM (peak)	≤2 percent		≤2 percent	
Phase Noise (rms)				
1 Hz - 10 Hz	≤1.5 degrees		≤1.5 degrees	
10 Hz - 32 Hz	≤1.5 degrees		≤1.5 degrees	
32 Hz - 1 kHz	≤4 degrees		≤4 degrees	
1 kHz - 6 MHz	≤2 degrees		≤2 degrees	
	<u>QPSK</u>	<u>BPSK</u>		
Command/range channel PN chip skew (peak)	≤0.01 chip	NA	NA	
PN chip asymmetry (peak)	≤0.01 chip	NA	NA	

Table 6-4. Salient Characteristics for TDRSS SSA Forward Service (cont'd)

Parameter (Note 1)	**PSK Modulation** (Note 1)		**PM Modulation** (Note 1)
	QPSK	BPSK	
PN chip rate (peak) relative to absolute coherent with carrier rate	≤0.01 chips/sec at PN code chip rate	NA	NA

Note:

1. The definitions and descriptions of the salient characteristics are provided in Appendix E.
2. These values are the TDRSS contributions for data asymmetry, data transition time, and data bit jitter, assuming perfect forward service data is provided to the WSC. The actual contributions by the NISN data transport system are negligible compared to those contributed by the TDRSS, since the WSC reclocks the data before it is processed by the WSC into the forward service signal.

Table 6-5. SSA Forward Service Real-Time Configuration Changes

Real-Time Configuration Changes	**GCMR**	**OPM**	**Forward Service Signal Interruption**
Customer Receiver Center Frequency	98/04	OPM 03	Yes
Doppler Compensation Inhibit	98/08	OPM 11	No
Doppler Compensation Reinitiation	98/04	OPM 03	No
Forward Service Reacquisition (note 1)	98/03	OPM 02	Yes
Forward PSK Service Sweep Request (refer to Table 6-1 note 5)	98/05	OPM 04	Yes
Forward PM Service Sweep Request (refer to Table 6-2 note 5)	98/05	OPM 04	No
Data Rate	98/04	OPM 03	No
Polarization	98/04	OPM 03	Yes
Initiation or termination of the command channel PN code (note 2)	98/04	OPM 03	No
Forward Service Normal/High Power Mode EIRP Change	98/06	OPM 06	No

Notes:

1. Forward service reacquisition is a TDRSS reinitiation of forward link service by applying a 1 MHz frequency offset for 3 seconds to the predicted customer receive frequency specified in the customer's service specification code (refer to paragraph 10.2.2).
2. Initiation of the command channel PN code enables the range channel. Termination of the command channel PN code disables the range channel.

c. At the start of the TDRSS SSA forward service as defined by the SHO, the TDRS will radiate, in the direction of the customer platform, a signal compatible with the TDRSS SSA forward service signal parameters listed in Table 6-1 (PSK) or Table 6-2 (PM) whichever is applicable. The signal will be transmitted at the scheduled EIRP consistent with the values listed in Table 6-3. The EIRP directed towards the customer platform is dependent upon the customer providing an ephemeris uncertainty within the values defined in Table 6-3. The use of TDRSS SSA forward service high-power operation is restricted and must be coordinated with the GSFC MSP.

d. The customer platform receiving system will search for and acquire the command channel PN code (if applicable) and carrier. Normally, a customer MOC will not be transmitting forward service data to the NISN data transport system until the forward service signal has been acquired by the customer platform and the acquisition verified by the customer MOC from customer platform return service telemetry. If the NASA fourth generation standard transponder is used, its design implementation requires that there be no data transitions during the signal acquisition process, while others may merely result in longer acquisition times. Data transmission is inhibited by WSC during PM carrier frequency sweep.

e. For QPSK modulation, the customer platform receiving system will search for and acquire the range channel PN code upon acquisition of the command channel PN code and carrier.

f. Depending upon the customer platform receiving system design, upon completion of forward link acquisition and subsequent customer platform transition to signal tracking, the customer platform transmitting system may either switch to a coherent mode or remain in a noncoherent mode until commanded by the customer MOC to switch.

g. The WSC will continue Doppler compensation of the TDRSS SSA forward service signal unless requested by the customer MOC to inhibit the Doppler compensation.

h. T_{acq} in the customer platform receiver is a function of the customer platform receiver design and signal-to-noise density ratio. For the purpose of an example, Table 6-6 provides the acquisition characteristics for the fourth generation transponder when receiving an SSA QPSK signal. The T_{acq} values listed in Table 6-6 are contingent on the customer MOC defining the customer platform receiver center frequency, f_o, to an accuracy of $\pm$700 Hz in each service support schedule add request (SAR). The customer platform forward service acquisition time must be considered in determining the overall return service acquisition time for customer platform with a coherent mode of operation.

i. Appendix A provides example link calculations for the TDRSS SSA forward service.

Table 6-6. SSA Forward Service Example Acquisition Times for the Fourth Generation NASA Standard Transponder

S/N_0 (notes 1, 3)	Command Channel PN Code (note 2)	Carrier (note 2)	Range Channel PN Code (note 2)	Total (note 2)
34 dB-Hz	≤ 20 sec	≤ 5 sec	≤ 10 sec	≤ 35 sec
≥ 37 dB-Hz	≤ 7 sec	≤ 5 sec	≤ 10 sec	≤ 22 sec

Notes:

1. S/N_0 is the signal to noise density ratio (dB-Hz) at the customer platform transponder input.
2. With a probability ≥ 90%. Carrier acquisition starts after the command channel PN code has been acquired. Range channel PN code acquisition starts after the carrier has been acquired.
3. For further specific information on the Fourth Generation user transponder, reference should be made to 531-RSD-IVGXPDR.

6.3 SSA Return Services

6.3.1 General

The RF signals provided by the customer platform to the TDRS and the characteristics of data provided at the WSC interface are defined in paragraphs 6.3.2 through 6.3.5. This discussion assumes that an appropriate return service has been scheduled and a data signal is present at the TDRS interface.

6.3.2 Signal Parameters

The TDRSS SSA return service signal parameters are listed in Table 6-7. The services are divided into 2 major groups, Data Group 1 (DG1) and Data Group 2 (DG2). DG1 services utilize spread spectrum modulation while DG2 services are non-spread. A description of the features inherent in the DG1 and DG2 services is discussed in paragraphs 6.3.2.2 and 6.3.2.3, respectively. Within each data group, there are several types of modulation. Additionally, both data groups support coherent and noncoherent modes. A description of these general characteristics is provided in paragraph 6.3.2.1.

6.3.2.1 General Modulation and Coherent/Noncoherent Description

a. SQPN Modulation. SQPN modulation is used to prevent simultaneous transitions of the I and Q PN sequences. For SQPN modulation, the PN chips of the I and Q channel are staggered by a 1/2 chip. For data configurations that use two PN spread channels, SQPN modulation must be used.

b. SQPSK Modulation. SQPSK modulation staggers one channel with respect to the other to prevent synchronous transitions. For non-spread signal configurations with identical I and Q symbol rates that are NRZ symbol formatted, SQPSK modulation must be used. The symbols of the Q channel are delayed 1/2 symbol relative to the I channel. For non-spread signal

Table 6-7. TDRSS SSA Return Service Signal Parameters

Parameter (Note 6)	**Description** (Note 6)
DG1 (note 1)	
Transmit carrier frequency (Hz) (note 5)	F_1
Carrier (F_1) reference (Hz)	
DG1 modes 1 and 3	$\frac{240}{221} \times FR$
DG1 mode 2	Customer platform transmitter oscillator
PN code modulation	
DG1 modes 1 and 2	SQPN, BPSK (see Appendix B and Table 6-8)
DG1 mode 3, I channel	PSK $\pm\pi/2$ radians
PN code chip rate (chips/sec)	$\frac{31}{[240 \times 96]} \times F_1$
PN code length (chips)	
DG1 modes 1 and 3	$(2^{10} - 1) \times 256$
DG1 mode 2	$2^{11} - 1$
PN code epoch reference	
DG1 mode 1	
I channel	Epoch (all 1's condition) synchronized to epoch (all 1's condition) of received forward service range channel PN code
Q channel (note 3)	Epoch delayed x + 1/2 PN code chips relative to I channel PN code epoch
DG1 mode 2	Not Applicable
DG1 mode 3, I channel	Same as DG1 mode 1 (I channel)
PN code family	
DG1 modes 1 and 3	Truncated 18-stage shift register sequences
DG1 mode 2	Gold codes
Data modulation:	
DG1 modes 1 and 2	Modulo-2 added asynchronously to PN code
DG1 mode 3:	
I channel	Modulo-2 added asynchronously to PN code
Q channel	PSK $\pm\pi/2$ radians

Table 6-7. TDRSS SSA Return Service Signal Parameters (cont'd)

Parameter (Note 6)	**Description** (Note 6)
DG1 (note 1) (Cont'd)	
Periodic convolutional interleaving (note 4)	Recommended for baud rates > 300 kbps
Data format	NRZ-L, NRZ-M, NRZ-S
Symbol format	NRZ, BiØ-L (Note 4)
DG1 mode 1 data rate restrictions	
Total (note 1)	0.1 - 300 kbps
I channel	0.1 - 150 kbps
Q channel	0.1 - 150 kbps
DG1 mode 2 data rate restrictions	
Total (note 1)	1 - 300 kbps
I channel	1 - 150 kbps
Q channel	1 - 150 kbps
DG1 mode 3 data rate restrictions	
Total (note 1)	I (max) + Q (max)
I channel	0.1 - 150 kbps
Q channel	1 kbps - 3 Mbps
DG1 $\frac{\text{Q channel power}}{\text{I channel power}}$ restrictions (note 2)	
Single data source-alternate I/Q bits	1:1
Single data source-identical data	1:1 to 4:1
Single data source-single data channel	NA
Dual data sources	1:1 to 4:1
DG2 (note 1)	
Transmit carrier frequency (note 5)	F_2
Carrier (F_2) reference (Hz)	
DG2 Coherent	$\frac{240}{221} \times F_R$
DG2 Noncoherent	Customer platform oscillator
Data modulation (note 1)	BPSK SQPSK, or QPSK (refer to Appendix B and Table 6-8)

Table 6-7. TDRSS SSA Return Service Signal Parameters (cont'd)

Parameter (Note 6)	**Description** (Note 6)
DG2 (note 1) (cont'd)	
Periodic convolutional interleaving (note 4)	Recommended for baud rates > 300 kbps
Symbol format	NRZ, Bi∅-L
Data format	NRZ-L, NRZ-M, NRZ-S
Data rate restrictions	
Total (note 1)	I (max) + Q (max)
I channel	1 kbps - 3 Mbps
Q channel	1 kbps - 3 Mbps
DG2 $\frac{\text{I channel power}}{\text{Q channel power}}$ restrictions	
Single data source-alternate I/Q bits	1:1
Single data source-alternate I/Q encoded symbols	1:1
Single data source-single data channel	NA
Dual data sources	1:1 to 4:1

Notes:

1. Customer platform data configurations, including specific data rate restrictions for coding and formatting, are defined in Table 6-8 for TDRSS SSA return service (refer also to Appendix B). Unless otherwise stated, the data rate restrictions given in this table assume rate 1/2 convolutional encoding and NRZ formatting.
2. For DG1, the Q/I power parameter range can vary from 1:1 to 4:1 continuously during specification of applicable parameter values in the DSMC scheduling database and during real-time service reconfiguration. However if this parameter is respecified in schedule requests to the DSMC (refer to paragraph 10.2.2), it is expressed as the ratio of two single-digit integers.
3. The Q channel PN code sequence must be identical to the I channel PN code sequence; but, offset x + 1/2 PN code chips, where x ≥ 20,000. The value of x is defined by the PN code assignment for a particular customer platform (refer to 451-PN CODE-SNIP).
4. Periodic convolutional interleaving (PCI) recommended on S-band return services for channel baud rates > 300 kbps. Biphase symbol formats are not allowed with PCI. When interleaving is not employed for channel baud rates > 300 kbps, S-band return performance may not be guaranteed.
5. The center frequency, f_o, of the customer platform transmitter must be defined by the customer MOC in its service specification code to an integral multiple of 10 Hz.
6. Unless otherwise noted, all data rate values are to be interpreted as data bit rates, and not as data symbol rates.

configurations that use biphase symbol formatting on either channel and the baud rate of the two channels are identical, SQPSK modulation is used and the transitions of one channel occur at the mid-point of adjacent transitions of the other channel.

c. QPSK Modulation. QPSK modulation is available when there is no relation between the I and Q channel transitions. For dual data source configurations, in which one or both channels are not spread and SQPSK is not required, QPSK modulation is used.

d. BPSK Modulation. BPSK modulation is available for single data source configurations that use only one channel of the link.

NOTES

For SQPN and SQPSK modulation, the spectral characteristics of a customer platform saturated power amplifier will, to a great degree, retain the spectral characteristics of the band-limited input signal to that amplifier. This should result in better control of out-of-band emissions, which, in turn, provides more efficient communications and less interference to customer platform using adjacent frequency channels on the TDRS links.

For non-spread SSA services, PSK subcarrier phase modulation (PCM/PSK/PM) and direct phase modulation (PCM/PM) may also be supported by the SN. However, its use and customer specific supporting characteristics must be coordinated with the GSFC MSP.

e. Coherent Mode. For coherent modes, the customer platform transmitted return link carrier frequency and PN code clock frequency (if applicable) are derived from the customer platform received forward link carrier frequency. For coherent PN spread return links, the return PN code length is identical to the length of the received forward service range channel PN code. The customer return I channel PN code epoch is synchronized with the epoch of the received forward service range channel PN code. Two-way Doppler measurements and range measurements (if PN spread) are available.

f. Noncoherent Mode. For noncoherent modes, the customer platform transmitted return link carrier frequency and PN code clock frequency (if applicable) are derived from an on-board local oscillator. The customer platform transmit frequency for noncoherent service must be defined by the customer MOC to an accuracy of $\pm$700 Hz in its service specification code when requesting TDRSS SSA return service (refer to paragraph 10.2.2). For customers whose frequency uncertainty is greater than $\pm$700 Hz, an expanded frequency search capability is available after service start.

g. Asynchronous Data Modulation. The data modulation is asynchronous to the carrier and the channel PN code (if applicable). This prevents Doppler variations of the forward service carrier and PN code frequencies from affecting the return service data rate.

6.3.2.2 DG1 Signal Parameters

DG1 signal parameters are subdivided into three modes of operation, DG1 modes 1, 2, and 3. For all DG1 modes, the PN code clock must be coherently related to the transmitted carrier frequency. This feature permits the customer platform transmitter to use a common source for generating the carrier and the PN code clock frequencies. 451-PN CODE-SNIP defines all the salient characteristics for the DG1 PN code libraries. The agency Spectrum Manager responsible for PN code assignments will allocate a customer platform-unique PN code assignment from these libraries. The GSFC Spectrum Manager is responsible for NASA PN code assignments. The three DG1 modes are distinguished as follows:

a. DG1 Mode 1. DG1 mode 1 must be used when range and two-way Doppler measurement (coherent transponder operations) are required concurrently with return service low-rate data transmission. Return service signal acquisition by the WSC for DG1 mode 1 is possible only when the scheduled TDRSS (SSA or MA) forward service signal is acquired by the customer platform and the PN code and carrier transmitted by the customer platform are coherently related to the forward service signal from the TDRS. If the TDRSS forward service signal becomes unavailable to the customer platform, the platform transmitter must switch to noncoherent transmitter operation (DG1 mode 2) (refer to paragraph 6.3.5.c.2). In order to reacquire the DG1 mode 2 signal, the return service must be reconfigured. The I and Q channel PN codes are generated from a single code generator. For DG1 mode 1 operation, the I and Q channel PN codes are identical but are offset by at least 20,000 chips. This separation is adequate for TDRSS to identify each data channel unambiguously without requiring a unique PN code for each channel.

b. DG1 Mode 2. DG1 mode 2 can be used when WSC return service signal acquisition is necessary without the requirement for prior customer platform signal acquisition of the TDRSS (SSA or MA) forward service (noncoherent transponder operation). The customer platform transmit frequency for DG1 mode 2 service must be defined by the customer MOC to an accuracy of $\pm$700 Hz in its service specification code when requesting TDRSS SSA return service (refer to paragraph 10.2.2). For customers whose frequency uncertainty is greater than $\pm$700 Hz, an expanded frequency search capability of $\pm$3 kHz is available after start of the return service. For DG1 mode 2, the I and Q channel PN codes are unique 2^{11}-1 Gold Codes.

c. DG1 Mode 3. DG1 mode 3 can be used when range and two-way Doppler measurements (coherent transponder operations) are required concurrently with return service high-rate data transmission. Restrictions on DG1 mode 3 signal acquisition are identical to those for DG1 mode 1. In DG1 mode 3, the Q channel must contain only data and no PN code.

d. Functional Configurations. Table 6-8 lists the DG1 SSA return service functional configurations and a further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in section B.3.2.

6.3.2.3 DG2 Signal Parameters

DG2 signal parameters are subdivided into two modes of operation, DG2 coherent and noncoherent. DG2 must be used when the return service data rate equipment exceeds the capability of DG1 operations. DG2 operations cannot provide TDRSS range tracking because PN code modulation is not used. The two DG2 modes are distinguished as follows:

a. DG2 Coherent. Return service signal acquisition by the WSC for DG2 coherent is possible only when the scheduled TDRSS (SSA or MA) forward service signal is acquired by the customer platform and the carrier transmitted by the customer platform is coherently related to the forward service signal from the TDRS. TDRSS two-way Doppler tracking can be provided when the DG2 carrier is coherently related to the TDRSS (SSA or MA) forward service carrier frequency.

b. DG2 Noncoherent. The DG2 carrier is independent of the TDRSS (SSA or MA) forward service carrier frequency. The customer platform transmit frequency for DG2 noncoherent service must be defined by the customer MOC to an accuracy of $\pm$700 Hz in its service specification code when requesting TDRSS SSA return service (refer to paragraph 10.2.2). For customers whose frequency uncertainty is greater than $\pm$700 Hz, an expanded frequency search capability of $\pm$3 kHz for SQPSK DG2 services and $\pm$35 kHz for BPSK and QPSK DG2 services is available after start of the return service.

NOTES

For non-spread SSA services, PSK subcarrier phase modulation (PCM/PSK/PM) and direct phase modulation (PCM/PM) may also be supported by the SN. However, its use and customer specific supporting characteristics must be coordinated with the GSFC MSP.

c. Functional Configurations. Table 6-8 lists the DG2 SSA return service functional configurations and a further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in section B.3.3.

Table 6-8. SSA Return Service Configurations

Return Service Configuration[10]				Source Data Rate Restrictions and Availability[8,9]					
				DG1 Mode				DG2 Mode	
				1[1] and 2[1,4]		3[2]		Coherent[3] and Noncoherent[3,4]	
				Data format	Data rate	Data format	Data rate	Data format	Data rate
Single Data Source	BPSK	Rate 1/2 coded		NRZ	≤150 kbps[1]	-	-	NRZ	1 kbps – 3 Mbps[5]
				NRZ with biphase symbols	≤75 kbps[1]			NRZ with biphase symbols	1 kbps – 1.5 Mbps[5,6]
		Rate 1/3 coded		-	-	-	-	NRZ	1 kbps – 2 Mbps[5]
								NRZ with biphase symbols	1 kbps – 1 Mbps[5,6]
		Uncoded		[7]	[7]	-	-	[7]	[7]
	SQPN	Identical I & Q channel data	Rate 1/2 coded	NRZ	≤150 kbps	-	-	-	-
				NRZ with biphase symbols	≤75 kbps				
			Uncoded	[7]	[7]	-	-	-	-
	SQPSK	Rate 1/2 coded alternate I/Q encoded symbols		-	-	-	-	NRZ	1 – 300 kbps
	SQPN[1] or SQPSK[3]	Alternating I/Q data	Individually rate 1/2 coded	NRZ	≤300 kbps	-	-	NRZ	1 kbps – 6 Mbps[5]
			Individually rate 1/3 coded	-	-	-	-	NRZ	1 kbps – 4 Mbps[5]
			Uncoded	[7]	[7]	-	-	[7]	[7]
Dual Data Sources (data rates are for each source separately)	SQPN[1], QPSK[2,3] or SQPSK[3]	Rate 1/2 coded		NRZ	≤150 kbps	NRZ	I: 0.1-150 kbps Q: 1 kbps – 3 Mbps	NRZ	1 kbps – 3 Mbps[5]
				NRZ with biphase symbols	≤75 kbps	NRZ with biphase symbols	I: 0.1-75 kbps Q: 1 kbps – 1.5 Mbps[5,6]	NRZ with biphase symbols	1 kbps – 1.5 Mbps[5,6]
		Rate 1/3 coded		-	-	NRZ	Q: 1 kbps – 2 Mbps	NRZ	1 kbps – 2 Mbps[5]
						NRZ with biphase symbols	Q: 1 kbps – 1 Mbps[5,6]	NRZ with biphase symbols	1 kbps – 1 Mbps[5,6]
		Uncoded		[7]	[7]	[7]	[7]	[7]	[7]

Table 6-8. SSA Return Service Configurations (cont'd)

✓ Configuration supported
\- Configuration not supported

NOTES:

1. For DG1 mode 1 and 2 configurations, where the minimum source data rates are 0.1 kbps for DG1 mode 1 and 1 kbps for DG1 mode 2:
   a. For data on a single I or Q channel, but not both channels: BPSK modulation is used where the data is modulo-2 added to the PN code.
   b. For data on both the I and Q channels: SQPN modulation is used and the SN supports I:Q power ratios of 1:1 to 1:4 for all the configurations, except the alternating I and Q data bit configuration, which requires a balanced I:Q power ratio.
   c. For the alternating I/Q data bit configuration: the SN requires the I channel lead the Q channel by a half symbol. Similarly, the SN requires the I and Q channels be independently differentially formatted (-M,-S).
2. For DG1 mode 3 configurations:
   a. The modulation is QPSK, where the I channel data is modulo-2 added to the PN code, and the Q channel data directly modulates the carrier at $+\pi/2$ radians.
   b. The SN supports I:Q power ratios of 1:1 to 1:4.
   c. Rate 1/3 coding is supported for the Q channel only. (Rate 1/2 coding is supported on both the I and Q channels.)
3. For DG2 configurations:
   a. For single data source configurations with data on one channel: BPSK modulation is used.
   b. For single data source configurations with data on both channels: SQPSK modulation and an I:Q power ratio of 1:1 is used. For the alternate I/Q bit configuration, the SN requires the I and Q channels be independently differentially formatted (-M,-S).
   c. For dual data source configurations: SQPSK must be used when there are identical baud rates on the I and Q channels (see paragraph 6.3.2.1.b); QPSK is used for all other configurations; for both SQPSK and QPSK, either an I:Q power ratio of 1:1 or 4:1 is supported. For unbalanced QPSK, the I channel must contain the higher data rate and when the data rate on the I channel exceeds 70 percent of the maximum allowable data rate, the Q channel data rate must not exceed 40 percent of the maximum allowable data rate on that Q channel.
4. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of ± 700 Hz. If a customer cannot accurately define their transmit frequency to within ± 700 Hz, a customer can request a reconfiguration which would expand the oscillator frequency search to ± 3 kHz for DG1 and SQPSK DG2 configurations and ± 35 kHz for BPSK and QPSK DG2 configurations after the start of service.
5. Periodic convolutional interleaving (PCI) recommended on S-band return service for channel baud rates > 300 kbps. When interleaving is not employed for channel baud rates > 300 kbps, S-band performance may not be guaranteed.
6. Biphase symbol formats are not allowed with PCI. Use of biphase symbol formats on S-band services at baud rates > 300 kbps should be coordinated with the GSFC MSP.
7. For all configurations and modes, the SN is capable of providing SSA support of uncoded links; however, performance is not guaranteed in RFI and must be coordinated with the GSFC MSP.
8. TDRSS may be capable of supporting other return signal configurations, such as residual carrier Phase Modulation signals; however, performance will have to be handled on a case-by-case basis with the GSFC MSP.
9. Unless otherwise noted, all data rates are to be interpreted as data bit rates, and not as data symbol rates. Refer to paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities.
10. Appendix B describes the functional configurations and associated I-Q channel and data polarity ambiguities. Additionally, Figure B-10 depicts the SN supported convolutional coding schemes.

6.3.3 Communications Services

To obtain TDRSS SSA return service performance defined in this paragraph, the customer platform transmitted signal must meet the requirements found in Table 6-9 and signal characteristics specified in Table 6-12. The TDRSS SSA return service performance defined in this paragraph also assumes return service operation in an AWGN environment. Appendix G discusses performance degradations to the TDRSS SSA return service due to RFI. Example link calculations are provided in Appendix A. TDRSS SSAR supports customers with an ephemeris uncertainty as defined in Table 6-9 and dynamics, described as non-powered flight and powered flight, as defined in Table 6-10.

6.3.3.1 Acquisition

The SSAR service supports acquisition for customer platforms operating under non-powered flight dynamics as defined in Table 6-10. SSAR acquisition will be protected against false WSC lock to: interfering customer platform PN codes, customer platform PN code sidelobes, and carrier recovery. The SSAR total channel acquisition times (T_{acq}) are given in Table 6-9 and are the sum of the following:

a. PN (DG1 only) and carrier acquisition time

b. Symbol/Decoder synchronization time or Symbol/Deinterleaver/Decoder synchronization time (if deinterleaving is applicable).

T_{acq} assumes that the customer platform return service signal is present at the WSC at the start time of the scheduled return service support period and the process is described below.

a. PN code (if applicable) and carrier acquisition will commence upon the start of the scheduled return service support period.

b. After PN code (if applicable) and carrier acquisition is achieved, TDRSS tracking services data is available.

c. Symbol/Decoder and Symbol/Deinterleaver/Decoder synchronization times will be measured from the time when the carrier acquisition is achieved to the time when the decoder synchronization is achieved. Decoder synchronization is achieved when the Viterbi decoder has selected and implemented the correct blocking of the input symbols (into groups of (G1,G2) symbol pairs for rate 1/2 codes, or (G1,G2,G3) symbol triplets for rate 1/3 codes).

d. After symbol/decoder and symbol/deinterleaver/decoder synchronization is achieved, SSA return service channel data is available at the WSC interface.

e. To minimize return data loss, it is recommended that the customer platform transmit idle pattern on its data channels until after it has observed (via the UPD data) that the WSC has completed all of its data channel signal acquisition processes.

Table 6-9. TDRSS SSA Return Service

Parameter (Note 7)	Description (Note 7)	
Field of View (FOV) (each TDRS)	Primary ±22 degrees east-west ±28 degrees north-south (rectangular)	Extended Elliptical (F8-F10) 24.0 degrees inboard east-west 76.8 degrees outboard east-west ±30.5 degrees north-south
Customer Ephemeris Uncertainty (along the customer orbital track)	$\leq \pm$ 9 sec	$\leq \pm$ 7.8 sec
TDRS antenna polarization (note 4)	RHC or LHC selectable	
TDRS antenna axial ratio (maximum)	1.5 dB over 3 dB beamwidth	
Receive frequency band (see paragraph 6.3.3.5.b)	2200 MHz to 2300 MHz	
RF bandwidth (3dB, minimum)	10 MHz	
10^{-5} Bit Error Rate (notes 1, 2, 3):		
Orbital Dynamics	Powered and non-powered flight dynamics (defined in Table 6-10)	
Minimum Required P_{rec} for Rate 1/2 convolutional coding:	All P_{rec} values are in dBW	
DG1 modes 1 and 2	$-231.6 + 10\log_{10}$(data rate in bps)	
DG1 mode 3		
I channel	$-231.6 + 10\log_{10}$(data rate in bps)	
Q channel		
Data rate $\leq$ 1 Mbps	$-232.1 + 10\log_{10}$(data rate in bps)	
Data rate > 1 Mbps	$-231.2 + 10\log_{10}$(data rate in bps)	
DG2		
Data rate $\leq$ 1 Mbps	$-232.1 + 10\log_{10}$(data rate in bps)	
Data rate > 1 Mbps	$-231.2 + 10\log_{10}$(data rate in bps)	
Minimum Required P_{rec} for Rate 1/3 convolutional coding:	All P_{rec} values are in dBW	
DG1 mode 3, Q channel		
Data rate $\leq$ 1 Mbps	$-232.4 + 10\log_{10}$(data rate in bps)	
Data rate > 1 Mbps	$-231.6 + 10\log_{10}$(data rate in bps)	

Table 6-9. TDRSS SSA Return Service (cont'd)

Parameter (Note 7)	Description (Note 7)
10^{-5} Bit Error Rate (notes 1, 2, 3) (cont'd):	
Minimum Required P_{rec} for Rate 1/3 convolutional coding (cont'd):	
DG2	
Data rate $\leq$ 1 Mbps	$-232.4 + 10\log_{10}$(data rate in bps)
Data rate > 1 Mbps	$-231.6 + 10\log_{10}$(data rate in bps)
Acquisition (note 3):	
Orbital dynamics	Free-flight dynamics only (defined in Table 6-10)
Total Channel Acquisition Time (assumes the customer return service signal is present at the WSC at the start time of the return service support period)	Sum of the following: 1. PN (DG1 only) and carrier acquisition time 2. Symbol/Decoder synchronization time or Symbol/Deinterleaver/Decoder synchronization time (if deinterleaving is applicable)
PN Code (if applicable) and Carrier Acquisition:	
P_{rec}	$\geq$ -202.9 dBW or consistent with the P_{rec} for BER, whichever is greater
Acquisition Time ($P_{acq} \geq 90\%$):	
Coherent operations	$\leq$ 1 sec
Noncoherent operations with frequency uncertainty (note 5):	
$\leq \pm$ 700 Hz	$\leq$ 1 sec
$\leq \pm$ 3 kHz	$\leq$ 3 sec
$\leq \pm$ 35 kHz	$\leq$ 3 sec
Channel Decoder/Symbol Synchronization Acquisition (note 6):	
Minimum data bit transition density	$\geq$ 64 randomly distributed data bit transitions within any sequence of 512 data bits
Number of consecutive data bits without a transition	$\leq$ 64
P_{rec} (dBW)	consistent with the P_{rec} for BER

Table 6-9. TDRSS SSA Return Service (cont'd)

Parameter (Note 7)	Description (Note 7)
Acquisition (note 3) (cont'd):	
Channel Decoder/Symbol Synchronization Acquisition (note 6) (cont'd):	
Acquisition time (in seconds) with >99% probability:	
Biphase	< 1100/(Channel Data Rate in bps)
NRZ	< 6500/(Channel Data Rate in bps)
Channel Symbol/Deinterleaver (PCI)/ Decoder Synchronization Acquisition (note 6):	
Minimum data bit transition density	$\geq$ 64 randomly distributed data bit transitions within any sequence of 512 data bits
Number of consecutive data bits without a transition	$\leq$ 64
P_{rec} (dBW)	consistent with the P_{rec} for BER
Acquisition time (in seconds) with >99% probability:	
Rate 1/2 coding	Average: $\leq$ 36000/(Channel Data Rate in bps) Maximum: $\leq$ 66000/(Channel Data Rate in bps)
Rate 1/3 coding	Average: $\leq$ 26000/(Channel Data Rate in bps) Maximum: $\leq$ 46000/(Channel Data Rate in bps)
Signal Tracking	
Orbital dynamics	During Free Flight refer to paragraph 6.3.3.3.a During Powered Flight refer to paragraph 6.3.3.3.b
Reacquisition (powered and non-powered flight)	refer to paragraph 6.3.3.4
Duty Factor	100%

Notes:

1. The BER is for a customer platform transmitting a signal on an AWGN channel which complies with the constraints defined in Table 6-12. Refer to Appendix G for a discussion of the additional degradation applicable to TDRSS SSA return service performance due to S-band RFI.

Table 6-9. TDRSS SSA Return Service (cont'd)

Notes (cont'd):
2. The required customer P_{rec} must meet the P_{rec} for BER or signal acquisition, whichever is greater. Paragraph 6.3.3.2.b provides the required P_{rec} description for each possible SSAR data configuration. Refer to Appendix A, paragraph A.4, for a definition of P_{rec}. The minimum required P_{rec} equations for BER produce the minimum P_{rec} for a given data rate for all possible signal characteristics. CLASS analysis will produce a more accurate performance projection based upon desired customer signal characteristics, such as data rate, data type, and jitter values. SN support may be possible for customers whose P_{rec} is less than the required P_{rec} for 10^{-5} BER performance as long as the customer is willing to accept support on a best-effort basis and less than 100 percent coverage. Any customer interested in receiving this marginal SN coverage shall be required to negotiate all support with the GSFC MSP.
3. For PN code (if applicable) and carrier acquisition, the total (I+Q)P_{rec} must be $\geq$ -202.9 dBW for all configurations, except SQPSK DG2 and noncoherent $\pm$35 kHz expanded frequency uncertainty DG2 configurations which require the total (I+Q)P_{rec} to be $\geq$ -190.9 dBW. However, acquisition requires the P_{rec} to also be consistent with the P_{rec} required for BER.
4. Operational considerations may limit the choice of TDRS antenna polarization. The SSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.
5. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of $\pm$ 700 Hz. If a customer cannot accurately define their transmit frequency to within $\pm$ 700 Hz, a customer can request a reconfiguration which would expand the oscillator frequency search to $\pm$ 3 kHz for DG1 and SQPSK DG2 configurations and $\pm$ 35 kHz for BPSK and non-staggered QPSK DG2 configurations after the start of service.
6. For symbol/decoder synchronization and symbol/deinterleaver/decoder synchronization, the minimum symbol transition density and consecutive symbols without a transition must meet the specifications defined in Table 6-12. It is recommended that customers use G_2 inversion to increase symbol transition density. Additionally, biphase symbol formatting increases symbol transition density.
7. All data rate values (and notes which modify these values, based upon specific signal format and encoding restrictions) are to be interpreted as data bit rates, and not as data symbol rates.

Table 6-10. Customer Dynamics Supported through TDRSS SSAR Service

Parameter	Non-powered Flight Dynamics	Powered Flight Dynamics
$\dot{R}$	$\leq$ 12 km/sec	$\leq$ 15 km/sec
$\ddot{R}$	$\leq$ 15 m/sec^2	$\leq$ 50 m/sec^2
$\dddot{R}$	$\leq$ 0.02 m/sec^3	$\leq$ 2 m/sec^3

f. Requirements for bit error probability and symbol slipping take effect at the time decoder synchronization is achieved.

NOTE

Data and symbol transition densities values higher than the minimums required will reduce these acquisition times.

6.3.3.2 Bit Error Rate (BER)

Table 6-9 provides P_{rec} equations that will result in a customer achieving a BER of 10^{-5} for TDRSS compatible signals. The BER P_{rec} equations are applicable for either powered or non-powered flight dynamics and the following conditions:

a. Data Encoding. Convolutional encoding (rate 1/2 or rate 1/3) should be used for all customer platform SSA transmissions both to minimize P_{rec} and as an RFI mitigation technique. Detailed coding design is described in Appendix B. Reed-Solomon decoding is available to WDISC customers; typical, performance is given in Appendix K.

NOTE

For all configurations and modes, the SN is capable of providing SSAR support of uncoded links; however, performance is not guaranteed in RFI and must be coordinated with the GSFC MSP.

b. Received Power. P_{rec} is in units of dBW. The customer project, in determining its design requirements for minimum customer platform EIRP, must take into account customer platform transmit antenna pointing losses, the space loss between the customer platform and the TDRS, and the polarization loss incurred between the customer platform transmit antenna and the TDRS receive antenna. The maximum TDRS receive antenna axial ratio is given in Table 6-9 (also refer to Appendix A). For DG1 and DG2 services, the following conditions apply:

1. Balanced Power Single Data Source-Identical Data on the I and Q Channels (DG1 mode 1 and 2 only). For a customer platform synchronously transmitting identical data on the I and Q channels (single data source-identical data) with a balanced I and Q channel power division, the total (I+Q) P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 6-9, where data rate is the single data source data rate. Refer to Appendix B for further information on this data configuration.

2. Balanced Power Single Data Source-Alternate I/Q Bits (DG1 mode 1 and 2 and DG2). For a customer platform transmitting alternate I and Q data

bits from a data source (single data source-alternate I/Q bits), the total (I+Q)P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 6-9, where data rate is the single data source data rate prior to separation into the I and Q channels. The Q/I (power) must be equal to 1:1. Refer to Appendix B for further information on this data configuration.

3. Balanced Power Single Data Source-Alternate I/Q Encoded Symbols (DG2 only). For a customer platform transmitting alternate I and Q encoded symbols from a data source (single data source-alternate I/Q encoded symbols), the total (I+Q)P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed Table 6-9, where data rate is the single data source data rate prior to the rate 1/2 encoder. The Q/I (power) must be equal to 1:1. Refer to Appendix B for further information on this data configuration.

4. Unbalanced Power Single Data Source-Identical Data on the I and Q Channels (DG1 mode 1 and 2). For a customer platform synchronously transmitting identical data on the I and Q channels (single data source-identical data) having unbalanced I and Q channel power division, the stronger power channel P_{rec} must be consistent with P_{rec} for a 10^{-5} BER listed in Table 6-9, where data rate is the single data source data rate. The weaker power channel P_{rec} need not be consistent with the P_{rec} for a 10^{-5} BER listed in Table 6-9. The Q/I (power) must not exceed 4:1. Refer to Appendix B for further information on this data configuration.

5. Dual Data Sources (DG1 and DG2). For a customer platform transmitting independent data on the I and Q channels (dual data sources), each channel's P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 6-9, where data rate is that channel's data rate. Refer to Appendix B for further information on this data configuration.

6. Single Data Source with Single Data Channel (DG1 modes 1 and 2 and DG2). For a customer platform transmitting one channel , the channel's P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 6-9, where data rate is the channel data rate. Refer to Appendix B for further information on this data configuration.

c. Customer Degradations. Further reductions in the TDRSS SSA return service performance identified in Table 6-9 can occur. The TDRSS SSA return service will also be degraded due to RFI (refer to Appendix G). The TDRSS SSA return services and tracking services will be provided without degradation for user customer platform transmitted signal characteristics within the constraints specified in Table 6-12. Customer platform parameters exceeding these constraints can also degrade TDRSS SSA return service performance. Refer to paragraph 3.5 for guidelines if the constraints in this paragraph cannot be met. Definitions of user customer platform constraints are given in Appendix E.

d. Multipath. The WSC will provide lockup and interference protection from multipath signals reflected from the Earth.

e. Periodic Convolutional Interleaving. At baud rates above 300 kbps, symbol interleaving of the customer platform transmission is recommended for DG1 mode 3 and DG2 signals. Biphase symbol formats are not allowed with PCI. When interleaving is not employed at baud rates above 300 kbps, S-band performance may not be guaranteed. Deinterleaving is not supported for baud rates $\leq$ 300 kbps. The functional description of the (30,116) periodic convolutional interleaving of either rate 1/2 or rate 1/3 convolutional encoder symbols is defined in Appendix F.

6.3.3.3 Signal Tracking

TDRSS provides SSA return signal tracking (carrier, PN, symbol synchronization, convolutional deinterleaver synchronization, Viterbi decoder synchronization) for both powered and non-powered flight dynamics. During a customer SSA return service support period, loss-of-lock (carrier, symbol synchronization, and Viterbi decoder) indications appear in the periodically updated User Performance Data (UPD) (every 5 seconds).

a. Non-powered Flight Dynamics. For all valid return service signals operating under non-powered flight dynamics, the SSA return service shall maintain signal tracking for the following conditions:

   1. Cycle Slips. The mean time-between-cycle slip in the WSC carrier tracking loop for each TDRSS SSA return service will be 90 minutes minimum. This value applies at carrier tracking threshold, which is 3 dB less than the minimum P_{rec} for BER, and increases exponentially as a function of linear dB increases in P_{rec}. Cycle slips may result in channel and/or data polarity reversal. WSC can correct for these reversals under the same conditions as WSC can resolve channel and/or data polarity ambiguity as discussed in Appendix B. The time for the WSC to recover from a cycle slip will be consistent with the time required for the WSC receiver to detect and automatically reacquire the signal.

   2. Bit Slippage. For each TDRSS SSA return service operating with a minimum P_{rec} required consistent with the P_{rec} for BER and data transition densities greater than 40% for NRZ symbols or any transition density for biphase symbols, the minimum mean time between slips caused by a cycle slip in the WSC symbol clock recovery loop is either 90 minutes or 10^{10} symbol periods, whichever is greater. For an SSA return service operating with 1 dB more than the minimum P_{rec} required for BER, and NRZ symbol transition densities between 25% and 40%, the minimum mean time between slips is either 90 minutes or 10^{10} symbol periods, whichever is greater.

3. Loss of Symbol Synchronization. For each TDRSS SSA return service with either rate 1/2 or rate 1/3 convolutional encoding and data transition densities greater than 40% for NRZ symbols and any transition density for biphase symbols, the WSC symbol synchronization loop will not unlock for a P_{rec} that is 3 dB less than the minimum P_{rec} required for BER. For NRZ symbol transition densities between 25% and 40%, the WSC symbol synchronizer loop will not unlock for a P_{rec} that is 2 dB less than the minimum P_{rec} required for BER. In both cases, the BER performance will be degraded when the P_{rec} is less than the minimum required for BER.

b. Powered Flight Dynamics. TDRSS will provide signal tracking with a probability of more than 0.99 over 90 minutes for a customer with powered flight dynamics and an ephemeris uncertainty as defined in Table 6-9. This value applies at the carrier tracking threshold. The carrier tracking threshold for DG1 signals is a minimum P_{rec} of -201.4 dBW or the minimum P_{rec} for BER, whichever is greater. The carrier tracking threshold for DG2 signals is a minimum P_{rec} of -195.3 dBW or the minimum P_{rec} for BER, whichever is greater.

6.3.3.4 Reacquisition

While in the PN/carrier tracking state, a loss of lock condition induced by a cycle slip will be automatically detected and a reacquisition will be automatically initiated. For a customer platform that continues to transmit the minimum P_{rec} for acquisition and maintains with an ephemeris uncertainty as defined in Table 6-9, the normal total channel reacquisition time for either powered or non-powered flight dynamics will be less than or equal to that for the initial total channel acquisition for non-powered flight dynamics, with a probability of at least 0.99. If lock is not achieved within 10 seconds of loss of lock, an acquisition failure notification will be sent to the MOC and WSC will reinitiate the initial service acquisition process. TDRSS SSA return service does not support acquisition of customers with powered flight dynamics. Upon receipt of the loss-of-lock indications in the UPD, the customer MOC may request a TDRSS SSA return service reacquisition GCMR (refer to section 10). It is recommended that the customer MOC delay initiation of the GCMR for at least 35 seconds after initial receipt of the loss-of-lock indications in the UPD.

6.3.3.5 Additional Service Restrictions

a. Sun Interference. The TDRSS SSA return service performance will not be guaranteed when the center of the sun is within 4 degrees of the TDRS SSA receiving antenna boresight; however, this sun interference checking is a customer MOC responsibility. Additionally, the TDRSS SSA return service performance will not be guaranteed when the center of the sun is within 1 degree of the boresight of the WSC receiving antenna supporting the TDRS.

b. Frequency and Polarization. The TDRSS SSA return service can support customer platform with assigned frequencies anywhere within the 2200 to

2300 MHz band with either RHC or LHC polarization. The following restrictions apply:

1. The BER relationships of Table 6-9 are satisfied for center frequencies from 2205 to 2295 MHz (refer to Appendix D for power level restrictions into the 2290-2300 MHz band). For customer center frequencies below 2205 MHz or center frequencies above 2295 MHz, acceptable data service may be achieved when the customer's spectrum does not spill over the edges of the 2200 to 2300 MHz band.
2. Customer platform spectrum should be constrained so that the first null of the spectrum falls within the 2200 to 2300 MHz band.
3. In addition, customer platform should consider employing selectable polarization capability.
4. To avoid interference with MA return customers, the SN may restrict support to SSA only customers that operate LHC polarization at frequencies above 2280 MHz.
5. The SSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.

c. Mutual Interference. It is possible for the mutual interference between SSA customer platforms operating on the same polarization to become significant. The SN can provide tools to assist customers in interference prediction and interference mitigation.

NOTE

Frequency assignment and polarization selection for TDRSS SSA return service customers is performed during the mission planning phase.

6.3.4 Real-Time Configuration Changes

Changes to the operating conditions or configuration of a TDRSS SSA return service during a scheduled service support period are initiated by a Ground Control Message Request (GCMR) from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the GCMR at the WSC. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning WSC response times for GCMRs is provided in Section 10. Table 6-11 lists the SSA return service real-time configuration changes and their effects on the return service.

6.3.5 Acquisition Scenarios

The following acquisition scenarios identify only the technical aspects of TDRSS SSA return service signal acquisition by the WSC and do not include operational procedures related to acquisition. Acquisition is dependent upon the customer providing an ephemeris with a maximum uncertainty as defined in Table 6-9:

Table 6-11. SSA Return Service Real-Time Configuration Changes

Real-Time Configuration Changes	GCMR	OPM	Return Service Interruption
Return Service Reacquisition	98/03	OPM 03	Yes
Noncoherent Expanded User Spacecraft Frequency Uncertainty	98/07	OPM 07	No
Channel Data Rate	98/04	OPM 03	No
Noncoherent Transmit Frequency	98/04	OPM 03	Yes
Redefinition of customer minimum EIRP	98/04	OPM 03	Yes
Redefinition of customer maximum EIRP	98/04	OPM 03	No
I/Q Power Ratio	98/04	OPM 03	Yes
Channel Data Format	98/04	OPM 03	No
Channel Data Bit Jitter	98/04	OPM 03	No
DG1 Mode	98/04	OPM 03	Yes
Polarization	98/04	OPM 03	No
Data Group	98/04	OPM 03	Yes
DG2 Coherency (coherent or noncoherent)	98/04	OPM 03	Yes
Periodic Convolutional Interleaving	98/04	OPM 03	No
DG2 Carrier Modulation	98/04	OPM 03	Yes
Data Source/Channel Configuration	98/04	OPM 03	Yes
G_2 inversion	98/04	OPM 03	No
Frame Length	98/04	OPM 03	No
Frame Sync Word Length	98/04	OPM 03	No
Frame Sync Word Bit Pattern	98/04	OPM 03	No
Sync Strategy Parameters	98/04	OPM 03	No
Note: Items that are indicated to cause return service interruption will cause the WSC receiver to discontinue signal tracking and attempt to reacquire the return service signal after the appropriate reconfiguration. Additionally, any reconfigurations to the forward that cause forward link interruption will also cause return interruption for coherent return links. Any other reconfigurations of the WSC may momentarily affect signal tracking.			

a. <u>Coherent Modes (DG1 Modes 1 or 3 and DG2 Coherent)</u>

1. For optimal TDRSS performance, all coherent services should have the TDRSS forward and return services starting at the same time. If operational considerations require starting the TDRSS forward service before the return service, no reconfigurations of the forward service can be sent within 30 seconds of the start of the return service. A forward link sweep request OPM cannot be sent within 150 seconds of the start of the return service.

2. The customer platform P_{rec} must be compatible with the minimum P_{rec} required for BER and the other TDRSS SSA return service signal parameters listed in Table 6-9.

3. The WSC will open-loop point the TDRS SSA antenna in the direction of the customer platform.

4. At the service start time specified by the SHO, the WSC will begin the search for the customer platform signal based upon predicted range and Doppler. The WSC corrects the received customer platform signal for Doppler to allow for WSC implementation of receivers with narrow acquisition and tracking bandwidths. The Doppler correction used by WSC is either one-way (Forward Doppler compensation enabled) or two-way (Forward Doppler compensation inhibited). For coherent operation, the Doppler correction is based upon the forward service frequency.

5. After the forward service has been acquired, the WSC will acquire the customer platform signal (PN code (applicable to DG1 only) and carrier) within the time limits listed in Table 6-9. Return service will be achieved at the WSC receiver output within the total channel acquisition time limits listed in Table 6-9, which includes WSC symbol, deinterleaver (if applicable), and Viterbi decoder synchronization.

b. <u>Noncoherent (DG1 Mode 2 and DG2 Noncoherent)</u>

1. This mode of customer platform operation does not require a TDRSS (MA or SSA) forward service signal to be received by the customer platform. However, the customer platform transmitter must be commanded to turn on when noncoherent transmissions are desired, either by stored commands, on-board configuration settings, or direct commands from its customer MOC.

2. The customer platform P_{rec} must be compatible with the minimum P_{rec} required for BER and the other TDRSS SSA return service signal parameters listed in Table 6-9 .

3. The WSC will open-loop point the TDRSS SSA antenna in the direction of the customer platform.

4. At the service start time specified by the SHO, the WSC will begin the search for the customer platform signal based upon predicted Doppler.

The WSC corrects the received customer platform signal for Doppler to allow for WSC implementation of receivers with narrow acquisition and tracking bandwidths. The Doppler correction used by WSC is one-way and based on the customer platform transmission frequency stated in the SHO and any subsequent OPMs.

5. The WSC will acquire the customer platform signal (PN code (applicable to DG1 only) and carrier) within the time limits listed in Table 6-9. Return service will be achieved at the WSC receiver output within the total acquisition time limits listed in Table 6-9, which includes WSC symbol and Viterbi decoder synchronization.

c. DG1 Mode Transitions

1. DG1 Mode 2 to DG1 Mode 1 (or 3) Transitions. A TDRSS (MA or SSA) forward service must be scheduled to be established prior to customer MOC transmission of the GCMR to reconfigure the TDRSS for DG1 mode 1 (or 3) operations (refer to paragraph 6.3.5.a.(1)).

2. DG1 Mode 1 (or 3) to DG1 Mode 2 Transitions. When the customer platform switches to the noncoherent mode (DG1 mode 2), customer platform return service signal parameters (e.g., carrier and channel PN codes) are changed causing the WSC to drop TDRSS SSA return service signal lock. Customer platform transponders designed to automatically switch from a coherent transponder mode to a noncoherent mode when the TDRSS SSA/MA forward service signal is lost will result in WSC loss of SSA return service signal lock. Reconfiguration and reacquisition by the WSC is required and must be initiated by a GCMR from the customer MOC.

NOTE

Failure to observe these conventions may result in WSC rejection of reconfiguration messages, excessive acquisition times, and unnecessary loss of customer platform return service data.

d. DG2 Mode Transitions

1. DG2 noncoherent to DG2 coherent Transitions. A TDRSS (MA or SSA) forward service must be scheduled to be established prior to customer MOC transmission of the GCMR to reconfigure the TDRSS for DG2 coherent operations (refer to paragraph 6.3.5.a.(1)).

2. DG2 coherent to DG2 noncoherent Transitions. When the customer platform switches to the noncoherent mode, the resulting customer transmit frequency offset will probably cause the WSC to drop TDRSS SSA return service signal lock when the switch is made. If return service signal lock is lost, reconfiguration and reacquisition by the WSC is required and must be initiated by a GCMR from the customer MOC.

NOTE

Failure to observe these conventions may result in WSC rejection of reconfiguration messages, excessive acquisition times, and unnecessary loss of customer platform return service data.

Table 6-12. TDRSS SSA Return Service Customer Platform Signal Constraints

Parameter (Notes 1 and 2)	**Description** (Notes 1 and 2)
Minimum channel symbol transition density (Note 3)	≥128 randomly distributed symbol transitions within any sequence of 512 symbols
Consecutive channel symbols without a symbol transition	≤64 symbols
Symbol asymmetry (peak)	≤ ±3 percent
Symbol rise time (90 percent of initial state to 90 percent of final state)	≤5 percent of symbol duration but > 17 nsec
Symbol jitter and jitter rate (note 4)	≤ 0.1 percent
Phase imbalance	
DG1 modes 1 and 2	≤ ± 5 degrees
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≤ ± 5 degrees
Q channel baud rate > 1.024 Msps	≤ ± 3 degrees
DG2	
BPSK	
Baud rate ≤ 1.024 Msps	≤ ± 9 degrees
Baud rate > 1.024 Msps	≤ ± 3 degrees
QPSK	
Baud rate per channel ≤ 1.024 Msps	≤ ± 5 degrees
Baud rate per channel > 1.024 Msps	≤ ± 3 degrees
Gain Imbalance	
DG1 modes 1 and 2	≤ ± 0.50 dB
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≤ ± 0.50 dB
Q channel baud rate > 1.024 Msps	≤ ± 0.25 dB
DG2	
BPSK	
Baud rate ≤ 1.024 Msps	≤ ± 1.0 dB
Baud rate > 1.024 Msps	≤ ± 0.25 dB
QPSK	
Baud rate per channel ≤ 1.024 Msps	≤ ± 0.50 dB
Baud rate per channel > 1.024 Msps	≤ ± 0.25 dB

Table 6-12. TDRSS SSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1 and 2)	**Description** (Notes 1 and 2)
Phase nonlinearity (applies for all types of phase nonlinearities) (peak)	
DG1 modes 1 and 2	≤ 4 degrees over ±2.1 MHz
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≤ 4 degrees over ±2.1 MHz
Q channel baud rate > 1.024 Msps	≤ 3 degrees over ±3.5 MHz
DG2	
Baud rate per channel ≤ 1.024 Msps	≤ 4 degrees over ±1.0 MHz
Baud rate per channel > 1.024 Msps	≤ 3 degrees over ±3.5 MHz
Gain flatness (peak)	
DG1 modes 1 and 2	≤ 0.4 dB over ±2.1 MHz
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≤ 0.4 dB over ±2.1 MHz
Q channel baud rate > 1.024 Msps	≤ 0.3 dB over ±3.5 MHz
DG2	
Baud rate per channel ≤ 1.024 Msps	≤ 0.4 dB over ±1.0 MHz
Baud rate per channel > 1.024 Msps	≤ 0.3 dB over ±3.5 MHz
Gain slope (peak)	
DG1 modes 1 and 2	Not specified
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	Not specified
Q channel baud rate > 1.024 Msps	≤ 0.1 dB/MHz over ±3.5 MHz
DG2	
Baud rate per channel ≤ 1.024 Msps	Not specified
Baud rate per channel > 1.024 Msps	≤ 0.1 dB/MHz over ±3.5 MHz
AM/PM	
DG1 modes 1 and 2	≤ 15 degrees/dB
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≤ 15 degrees/dB
Q channel baud rate > 1.024 Msps	≤ 12 degrees/dB

Table 6-12. TDRSS SSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1 and 2)	**Description** (Notes 1 and 2)
AM/PM (cont'd)	
DG2	
Baud rate per channel $\leq$ 1.024 Msps	$\leq$ 15 degrees/dB
Baud rate per channel > 1.024 Msps	$\leq$ 12 degrees/dB
Noncoherent frequency stability (peak) (Notes 5, 6)	
$\pm$700 Hz customer oscillator frequency uncertainty	
1-sec average time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 1 \times 10^{-7}$
48-hr observation time	$\leq 3 \times 10^{-7}$
$\pm$ 3 kHz customer oscillator frequency uncertainty	
1-sec average time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 4.3 \times 10^{-7}$
48-hr observation time	$\leq 1.29 \times 10^{-6}$
$\pm$ 35 kHz customer oscillator frequency uncertainty	
1-sec average time	
Baud rate per channel $\leq$ 12.5 ksps	$\leq 7.37 \times 10^{-9}$
Baud rate per channel > 12.5 ksps	$\leq 26 \times 10^{-9}$
5-hr observation time	$\leq 3.77 \times 10^{-6}$
48-hr observation time	$\leq 11.3 \times 10^{-6}$
Incidental AM (peak)	
At frequencies >10 Hz for data rates <1 kbps;	
At frequencies >100 Hz for data rates $\geq$1 kbps	$\leq$5 percent
Spurious PM (rms)	
DG1	$\leq$ 2 degrees
DG2	
BPSK	$\leq$ 2 degrees
QPSK	
I/Q = 4:1	$\leq$ 2 degrees
I/Q = 1:1	$\leq$ 1 degree

Table 6-12. TDRSS SSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1 and 2)	**Description** (Notes 1 and 2)
Minimum 3-dB bandwidth prior to power amplifier	
DG1	$\geq$4.5 MHz or two times maximum baud rate, whichever is larger
DG2	$\geq$2 times maximum channel baud rate
Phase noise (rms) (Note 7)	
DG1 Mode 1	
Doppler Tracking Required	
All baud rates	
1 Hz – 10 Hz	≤1.0° rms
10 Hz – 1 kHz	≤1.0° rms
1 kHz – 6 MHz	≤1.5° rms
Doppler Tracking NOT Required (Note 8)	
Channel baud rate < 18 ksps	
1 Hz – 10 Hz	≤1.0° rms
10 Hz – 1 kHz	≤1.0° rms
1 kHz – 6 MHz	≤1.5° rms
Channel baud rate $\geq$ 18 ksps	
1 Hz – 10 Hz	≤ 25.0° rms
10 Hz – 1 kHz	≤ 2.2° rms
1 kHz – 6 MHz	≤ 2.0° rms
DG1 Mode 2	
Doppler Tracking Required	
All baud rates	
1 Hz – 10 Hz	≤ 2.0° rms
10 Hz – 100 Hz	≤ 1.0° rms
100 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 6 MHz	≤ 1.5° rms

Table 6-12. TDRSS SSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1 and 2)	**Description** (Notes 1 and 2)
Phase noise (rms) (Note 7) (cont'd)	
DG1 Mode 2 (cont'd)	
Doppler Tracking NOT Required (Note 8)	
Channel baud rate < 40 ksps	
1 Hz – 10 Hz	≤ 7.5° rms
10 Hz – 100 Hz	≤ 2.0° rms
100 Hz – 1 kHz	≤ 1.5° rms
1 kHz – 6 MHz	≤ 1.5° rms
Channel baud rate ≥ 40 ksps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 100 Hz	≤ 5.5° rms
100 Hz – 1 kHz	≤ 2.5° rms
1 kHz – 6 MHz	≤ 2.5° rms
DG1 Mode 3	
Doppler Tracking Required	
All baud rates	
1 Hz – 10 Hz	≤ 1.0° rms
10 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 6 MHz	≤ 1.5° rms
Doppler Tracking NOT Required (Note 8)	
Channel baud rate < 222.5 ksps	
1 Hz – 10 Hz	≤ 4.0° rms
10 Hz – 1 kHz	≤ 2.8° rms
1 kHz – 6 MHz	≤ 1.4° rms
Channel baud rate ≥ 222.5 ksps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 1 kHz	≤ 5.5° rms
1 kHz – 6 MHz	≤ 1.8° rms
DG2 Coherent	
Doppler Tracking Required	
All baud rates	
1 Hz – 10 Hz	≤1.0° rms
10 Hz – 1 kHz	≤1.0° rms
1 kHz – 6 MHz	≤2.0° rms

Table 6-12. TDRSS SSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1 and 2)	**Description** (Notes 1 and 2)
Phase noise (rms) (Note 7) (cont'd)	
DG2 Coherent (cont'd)	
Doppler Tracking NOT Required (Note 8)	
Channel baud rate < 18 ksps	
1 Hz – 10 Hz	≤3.8° rms
10 Hz – 1 kHz	≤2.3° rms
1 kHz – 6 MHz	≤2.0° rms
Channel baud rate between 18 ksps and 1.024 Msps	
1 Hz – 10 Hz	≤25.0° rms
10 Hz – 1 kHz	≤2.5° rms
1 kHz – 6 MHz	≤2.0° rms
Channel baud rate > 1.024 Msps	
1 Hz – 10 Hz	≤5.0° rms
10 Hz – 1 kHz	≤1.0° rms
1 kHz – 6 MHz	≤0.5° rms
DG2 Noncoherent	
Doppler Tracking Required	
All baud rates	
1 Hz – 10 Hz	≤ 2.0° rms
10 Hz – 100 Hz	≤ 1.0° rms
100 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 6 MHz	≤ 2.0° rms
Doppler Tracking NOT Required (Note 8)	
Channel baud rate < 12.5 ksps	
1 Hz – 10 Hz	≤ 5.0° rms
10 Hz – 100 Hz	≤ 1.0° rms
100 Hz – 1 kHz	≤ 1.0° rms
1 kHz – 6 MHz	≤ 2.0° rms
Channel baud rate between 12.5ksps and 1.024 Msps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 100 Hz	≤ 5.5° rms
100 Hz – 1 kHz	≤ 2.4° rms
1 kHz – 6 MHz	≤ 2.4° rms

Table 6-12. TDRSS SSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1 and 2)	**Description** (Notes 1 and 2)
Phase noise (rms) (Note 7) (cont'd)	
DG2 Noncoherent (cont'd)	
Doppler Tracking NOT Required (Note 8)	
Channel baud rate > 1.024 Msps	
1 Hz – 10 Hz	≤ 10.0° rms
10 Hz – 100 Hz	≤ 1.5° rms
100 Hz – 1 kHz	≤ 0.5° rms
1 kHz – 6 MHz	≤ 0.5° rms
In-band spurious outputs, where in-band is twice the maximum channel baud rate	
DG1 modes 1 and 2	≥ 23 dBc
DG1 mode 3	
Q channel baud rate ≤ 1.024 Msps	≥ 23 dBc
Q channel baud rate > 1.024 Msps	≥ 30 dBc
DG2	
Baud rate per channel ≤ 1.024 Msps	≥ 23 dBc
Baud rate per channel > 1.024 Msps	≥ 30 dBc
Out-of-band emissions	See Appendix D for allowable limits on out-of-band emissions, including spurs
I/Q symbol skew (relative to requirements for I/Q data synchronization where appropriate) (peak)	≤3 percent
I/Q PN chip skew (relative to 0.5 chip)	≤0.01 chip
PN chip rate (peak), DG1 mode 2 (relative to absolute coherence with carrier rate)	≤0.01 chips/sec at PN code chip rate
PN power suppression (noncoherent and coherent)	≤0.3 dB
Customer Antenna-Induced AM	≤3 dB
Customer Antenna-Induced PM	≤10 degrees
Data rate tolerance	≤±0.1 percent
I/Q power ratio tolerance	≤±0.4 dB
Permissible P_{rec} variation (without reconfiguration GCMR from customer MOC) (Note 9)	≤12 dB
Permissible rate of P_{rec} variation	≤10 dB/sec
Maximum P_{rec}	-149.7 dBW -157.7 dBW (SSA cross-support: DG1 mode 3)

Table 6-12. TDRSS SSA Return Service Customer Platform Signal Constraints (cont'd)

Notes:

1. The definitions and descriptions of the customer constraints are provided in Appendix E.
2. When a constraint value is listed for a baud rate range and data is transmitted on both channels, the maximum baud rate of the 2 channels should be used to determine the constraint value applicable.
3. It is recommended that customers use G2 inversion to increase symbol transition density. Additionally, biphase symbol formatting increases symbol transition density.
4. The symbol jitter and jitter rate are defined as the customer transmitted signal peak clock frequency jitter and peak clock jitter rate (sinusoidal or 3σ random) as a percent of the symbol clock rate.
5. The frequency stability requirements are valid at any constant temperature (±0.5° C) in the range expected during the mission. At a minimum, a temperature range of -10° C to +55° C shall be considered.
6. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of ± 700 Hz. If a customer cannot accurately define their transmit frequency to within ± 700 Hz, a customer can request a reconfiguration which would expand the oscillator frequency search to ± 3 kHz for DG1 and SQPSK DG2 configurations and ± 35 kHz for BPSK and QPSK DG2 configurations after the start of service.
7. Derivation of the phase noise requirements involved making assumptions about the distribution of the phase noise power in each frequency region. Since no phase noise PSD will exactly match the phase noise power distribution assumed for this derivation, phase noise PSDs which are close to violating the phase noise limits or phase noise PSDs which violate the phase noise limits should be evaluated on a case-by-case basis to determine their acceptability.
8. Applicable for customers that have no Doppler tracking requirement or can tolerate a total Doppler tracking error greater than 0.2 rad/sec.
9. The minimum SHO EIRP should reflect the minimum P_{rec} expected over the service period, where the P_{rec} can exceed this minimum by no more than 12 dB. An actual customer P_{rec} value that is 12 dB greater than the minimum may cause false PN lock or nonacquisition.

Section 7. KuSA Telecommunications Services

7.1 General

7.1.1 Available Services

TDRSS KuSA services include forward and return telecommunications services, and tracking services. Tracking services are discussed in Section 9. This section focuses on the RF interface between the TDRS and the customer platform. This interface is characterized by the technical requirements imposed and the operational capabilities provided by the TDRSS. The operational interfaces are described in further detail in Section 10. Data interfaces between the customer MOC and the SN are described in paragraph 3.6.

NOTE

> The DSMC issues Network Advisory Messages (NAMS) to provide up-to-date information on network conditions and constraints. These messages are accessible via the DSMC active NAMS web site at http://128.183.140.27/nam/wnserch.htm. At the time of publication of this revision, the TDRS F9 and F10 spacecraft are not operational. Prior to the next revision of this document, the GSFC MSP will use the NAMs as a means of letting customers know of any performance constraints associated with these spacecraft as well as any of the other TDRS.

7.1.2 Interface Definition

The RF interface between the TDRS and a customer platform is defined in terms of signal parameters, RF characteristics, and field of view.

a. The RF interface for forward service represents the transmission by a TDRS of an appropriately modulated signal at or greater than a minimum specified signal EIRP in the direction of the desired customer platform. KuSA forward (KuSAF) service is discussed in paragraph 7.2.

b. The RF interface for return service defines a minimum received power (P_{rec}) at the TDRS antenna input for a specified data quality at the WSC receiver output. KuSA return (KuSAR) service is discussed in paragraph 7.3.

NOTE

> The KuSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.

7.1.3 Customer Acquisition Requirements

Acquisition and reacquisition by the customer platform of the TDRS transmitted signal requires prediction by the customer MOC of the customer platform receive frequency over various projected time periods. Similarly, acquisition and reacquisition by the WSC of the customer platform signal requires prediction by the customer MOC of the customer platform transmitter frequency over various projected time periods. The frequency predictions are ultimately incorporated in the Schedule Order (SHO) as customer platform frequencies for the specific service support periods. Refer to Section 9 for additional information on TDRSS tracking services that can assist customers to predict their local oscillator frequencies.

7.1.4 TDRSS Acquisition Support to Customers

For each scheduled TDRSS service support period, the customer requirements for signal acquisition/reacquisition, and the TDRSS capabilities to aid acquisition/ reacquisition, are as follows:

a. Customer Epoch Uncertainty

   1. Autotrack. The maximum epoch time uncertainty of the applicable customer platform ephemeris supplied to the TDRSS shall be ±4.5 seconds and ±3.2 seconds for customer platform operations requiring the TDRSS KuSA return service autotrack process within the TDRSS Primary FOV and Extended Elliptical FOV, respectively. Similarly, the maximum epoch time uncertainty of the customer platform ephemeris shall be ±1.5 seconds for the TDRSS KuSA return service autotrack process within the TDRSS LEOFOV.

      NOTE

      KuSA forward and return autotrack service for the Extended Elliptical FOV will be supported on a best effort basis.

   2. Program track. The maximum epoch time uncertainty of the applicable customer platform ephemeris supplied to the TDRSS shall be ±4.5 seconds and ±3.2 seconds for customer platform operations using TDRSS KuSA open-loop pointing within the TDRSS Primary FOV and Extended Elliptical FOV, respectively.

   3. LEO Program track. The maximum epoch time uncertainty of the applicable customer platform ephemeris supplied to the TDRSS shall be ±1.5 seconds for customer platform operations requiring the TDRSS KuSA open-loop pointing for customers within the TDRSS LEOFOV.

b. Customer Frequency Uncertainty. The customer MOC must know the operating frequency of the customer platform to within ±5 kHz.

c. Frequency Sweep on the Forward Link. After the start of the forward link service, the TDRSS has a forward service frequency sweep capability of ±30 kHz.

d. Noncoherent Return Expanded Frequency Search. After the start of the return link service, the TDRSS has a return service expanded frequency search capability of ±20 kHz.

7.2 KuSA Forward Services

7.2.1 General

The characteristics of the data provided to the WSC interface and the RF signals provided by the TDRS to the customer platform during TDRSS KuSA forward services are described in paragraphs 7.2.2 through 7.2.5. This discussion assumes that an appropriate forward service has been scheduled and a data signal is present at the WSC interface.

7.2.2 Signal Parameters

The TDRSS KuSA forward service signal parameters are defined in Table 7-1. The center frequency, f_o, of the customer platform receiver must be defined by the customer MOC in its service specification code for TDRSS KuSA forward service (refer to paragraph 10.2.2). A description of the features inherent in the QPSK and BPSK signal parameters listed in Table 7-1 are discussed in paragraphs 7.2.2.1 and 7.2.2.2, respectively.

7.2.2.1 QPSK Signal Parameters

a. Unbalanced QPSK Modulation. The I channel is used to transmit the customer command data and is referred to as the command channel. The Q channel transmits a range signal and is referred to as the range channel. The command channel/range channel power ratio for QPSK forward service signals is +10 dB. This unbalanced QPSK modulation minimizes the power in the range channel to a level adequate for customer platform range channel acquisition and tracking. This feature increases the power in the command channel by 2.6 dB over that for balanced QPSK modulation without increasing customer platform receiver complexity, increasing customer platform command channel acquisition time, or decreasing TDRSS range tracking accuracy.

b. Spread Spectrum. All TDRSS KuSA forward services with data rates ≤300 kbps should incorporate spread spectrum modulation techniques to satisfy flux density restrictions imposed upon TDRSS forward services by the NTIA. This modulation scheme includes separate but simultaneous command and range channels. The command channel includes a rapidly acquirable PN code and contains the forward service data. The range channel is acquired separately and contains a PN code which satisfies the range ambiguity resolution requirements. The length of the command channel PN code is 2^{10}-1, where the length of the range channel PN code is 256 times the command channel PN code length. The customer platform command channel acquisition can precede customer platform range channel acquisition; this feature permits rapid acquisition of the range channel by limiting the range channel PN code

Table 7-1. TDRSS KuSA Forward Service Signal Parameters

Parameter	Description
TDRS transmit carrier frequency (Hz)	F
Carrier frequency arriving at customer platform (note 1)	F_R
Carrier frequency sweep (note 4)	$\pm$30 kHz
Carrier frequency sweep duration (note 4)	120 seconds
QPSK (PN modulation enabled)	
$\frac{\text{Command channel radiated power}}{\text{Range channel radiated power}}$	+10 dB
QPSK Command Channel	
Carrier frequency (Hz)	Transmit carrier frequency (F)
PN code modulation	PSK, $\pm$ π/2 radians
Carrier suppression	30 dB minimum
PN code length (chips)	2^{10} - 1
PN code epoch reference	Refer to 451-PN CODE-SNIP
PN code family	Gold codes
PN code chip rate (chips/sec)	$\frac{31}{1469 \times 96} \times F$
Data modulation	Modulo-2 added asynchronously to PN code
Data format (note 2)	Not applicable
Data rate restrictions (note 2)	1 kbps - 300 kbps
QPSK Range Channel	
Carrier	Command channel carrier frequency delayed π/2 radians
PN code modulation	PSK, $\pm$ π/2 radians
Carrier suppression	30 dB minimum
PN code chip rate	Synchronized to command channel PN code chip rate
PN code length (chips)	$(2^{10}$ - 1) x 256
PN code epoch reference	All 1's condition synchronized to the command channel PN code epoch.
PN code family	Truncated 18-stage shift register sequences

Table 7-1. TDRSS KuSA Forward Service Signal Parameters (cont'd)

Parameter	Description
BPSK (PN modulation disabled)	
Carrier frequency (Hz)	Transmit carrier frequency (F)
Data modulation	PSK, $\pm\pi/2$ radians
Carrier suppression	30 dB minimum
Data format (note 2)	Not Applicable
Data rate restrictions (notes 2, 3)	300 kbps - 25 Mbps

Notes:

1. The center frequency, f_o, of the customer platform receiver must be defined by the customer MOC in its service specification code to an integral multiple of 10 Hz. Doppler compensation will be available for $\dot{R} \leq 12$ km/sec. During periods of Doppler compensation, $F_R = f_o \pm E$ Hz; where f_o = nominal center frequency of customer platform receiver as defined by the customer MOC and $E = (500 \times \ddot{R}) + C$ for $\ddot{R} \leq 15$ m/sec^2 and C = 10 Hz. During periods of Doppler compensation inhibit, WSC will round-off the customer receive frequency contained in the SHO to the nearest multiple of 146.9 Hz, which will result in an additional frequency error of up to 73 Hz. If Doppler compensation is inhibited after the start of the forward service, a transition profile will be initiated to slowly change the frequency from the compensate profile to this integer multiple of 146.9 Hz.

   Forward service Doppler compensation will not increase the effective frequency rate of change seen at the customer receiver more than 28 Hz/sec relative to the frequency for a Doppler free carrier.
2. The forward data rate in this table is the baud rate that will be transmitted by the TDRSS (includes all coding and symbol formatting). For non-WDISC customers, forward data conditioning is transparent to the SN. These transparent operations should be performed by the customer prior to transmission to the SN data interface. Refer to paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities. Currently, the WSC data interface supports up to 7 Mbps; however, upgrades to support up to 25 Mbps are planned.
3. The SN is capable of supporting BPSK signals at data rates less than 300 kbps; however, its use will be controlled and must be coordinated with the GSFC MSP.
4. After the start of the KuSA forward service, if a customer MOC is unable to accurately define f_o (the nominal center frequency of the customer platform receiver), the forward service carrier frequency can be swept. The KuSA forward service frequency sweep will be initiated by the WSC at f_o-30 kHz and linearly swept to f_o+30 kHz in 120 seconds and held at f_o+30 kHz thereafter. The KuSA forward service frequency sweep does not impact simultaneous WSC Doppler compensation of the KuSA forward service carrier and PN code rate (if applicable).

search to only 256 chip positions while the range channel PN code itself contains 261,888 chips. The PN code chip rate is coherently related to the TDRS transmit frequency in all cases. This feature permits the customer platform receiver to use the receiver PN code clock to predict the received carrier frequency, thereby minimizing receiver complexity and reducing acquisition time. 451-PN CODE-SNIP defines all the salient characteristics for the forward range and command channel PN code libraries. The agency Spectrum Manager responsible for PN code assignments will allocate a customer platform-unique PN code assignment from these libraries. The GSFC Spectrum Manager is responsible for NASA PN code assignments.

c. Asynchronous Data Modulation. For data rates $\leq$ 300 kbps, the forward service data received at WSC from the NISN data transport system is directly modulo-2 added by WSC to the command channel PN code sequence. The forward service data will be asynchronous with the carrier and the PN code.

NOTE

When the command channel does not contain any actual forward service data, the forward service command channel signal is the command channel PN code sequence.

d. Functional Configurations. A further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in section B.2.2.

e. Doppler Compensation. The TDRSS KuSA forward service carrier frequency (F) and the PN chip rate transmitted by a TDRS can optionally be compensated by the WSC for Doppler. When compensated, the carrier, F_R, arrives at the customer platform receiving system within a predictable tolerance (E) of f_o as defined in Table 7-1. This feature minimizes the Doppler resolution requirements of the customer platform receiver and is available continuously to facilitate reacquisition by the customer platform in the event of loss of lock of the TDRSS KuSA forward service signal. Customers are encouraged to utilize Doppler compensation at all times. Doppler compensation may be inhibited and the TDRSS will transmit a fixed frequency KuSA forward service carrier and PN code chip rate.

7.2.2.2 BPSK Signal Parameters

a. BPSK Modulation. For data rates greater than 300 kbps, there is no PN code modulation and the customer data directly BPSK modulates the carrier by $\pm\pi/2$ radians.

NOTE

The SN is capable of supporting non-spread BPSK signals at data rates less than 300 kbps; however, its use will be controlled and must be coordinated with the GSFC MSP.

b. Asynchronous Data Modulation. The forward service data will be asynchronous with the carrier.

NOTE

When the command channel does not contain any actual forward service data, the forward service command channel signal is carrier only.

c. Functional Configurations. A further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in section B.2.2.

d. Doppler Compensation. The TDRSS KuSA forward service carrier frequency (F) transmitted by a TDRS can optionally be compensated by the WSC for Doppler. When compensated, the carrier, F_R, arrives at the customer platform receiving system within a predictable tolerance (E) of f_o as defined in Table 7-1. This feature minimizes the Doppler resolution requirements of the customer platform receiver and is available continuously to facilitate reacquisition by the customer platform in the event of loss of lock of the TDRSS KuSA forward service signal. Customers are encouraged to utilize Doppler compensation at all times. Doppler compensation may be inhibited and the TDRSS will transmit a fixed frequency KuSA forward service carrier.

7.2.3 Communications Services

The TDRSS KuSA forward services available are listed in Table 7-2. Table 7-3 lists their salient characteristics. The definitions for the parameters listed in Table 7-3 are contained in Appendix E.

7.2.4 Real-Time Configuration Changes

Changes to the operating conditions or configuration of a TDRSS KuSA forward service during a scheduled service support period are usually initiated by a Ground Control Message Request (GCMR) from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the GCMR at the WSC. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning WSC response times for the GCMRs is provided in Section 10. Table 7-4 lists the KuSA forward service real-time configuration changes and their effects on the forward service signal.

Table 7-2. TDRSS KuSA Forward Service

Parameter	Description		
Field of view (FOV) (each TDRS)	Primary (PFOV)	LEO (LEOFOV)	Extended Elliptical (EEFOV) (F8-F10)
	±22 degrees east-west ±28 degrees north-south (rectangular)	±10.5 degree conical	24.0 degrees inboard east-west 76.8 degrees outboard east-west ±30.5 degrees north-south
Customer Ephemeris Uncertainty (along the customer orbital track)	≤ ± 4.5 sec	≤ ± 1.5 sec	≤ ± 3.2 sec
TDRS antenna polarization (note 1)	RHC or LHC selectable		
	Autotrack (PFOV, LEOFOV, and EEFOV) (notes 3, 5)	LEO Program Track (LEOFOV)	Program Track (PFOV and EEFOV)
TDRS antenna axial ratio (maximum)			
Normal or high-power mode	1 dB over 3-dB beamwidth	1 dB over 3-dB beamwidth	1.5 dB
TDRS signal EIRP (minimum) (note 4)			
Normal power mode	+46.5 dBW	44 dBW	40.5 dBW
High power mode	+48.5 dBW	46 dBW	42.5 dBW
Transmit frequency (nominal) (note 2)	13.775 GHz ±0.7 MHz		
RF bandwidth (3dB, minimum)	50 MHz		
Duty factor	100 percent (normal and high power)		

Notes:

1. Operational considerations may limit choice of TDRS antenna polarization. The KuSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.

Table 7-2. TDRSS KuSA Forward Service (cont'd)

Notes (cont'd):
2. The customer MOC must include the best estimate of the customer platform receiver center frequency at the time of startup of each scheduled service support period in its service specification code (refer to paragraph 10.2.2). The TDRSS KuSA forward service carrier frequency is then implemented by WSC to the accuracy of the WSC frequency standard except during Doppler compensation. 3. EIRP values are for a TDRSS forward service with a TDRSS return autotrack service acquired. Forward service EIRP will default to high power program track values when: 1) a simultaneous return service with autotrack enabled is ongoing AND 2) TDRSS is in the autotrack acquisition process. Return service autotrack acquisition will be achieved within 10 seconds of KuSA return service P_{rec} consistent with the BER or autotrack acquisition, whichever is larger. Following return autotrack acquisition, the forward EIRP power mode reverts to the normal or high power mode specified in the SHO. 4. The autotrack EIRP will be transmitted towards a customer meeting the required ephemeris uncertainties for the Primary FOV, LEOFOV, or the Extended Elliptical FOV. The program track EIRP will be transmitted towards a customer meeting the required ephemeris uncertainties for the Primary FOV or the Extended Elliptical FOV. The LEO program track EIRP will be transmitted towards a customer meeting the required LEO ephemeris uncertainties for the LEOFOV. Customers may experience better performance through the KuSA program track and LEO program track services than listed in this document. Performance improvements particular to each customer should be discussed with the GSFC MSP. 5. KuSA forward autotrack service for the Extended Elliptical FOV will be supported on a best effort basis.

7.2.5 Acquisition Scenarios

The following acquisition scenarios identify only the technical aspects of TDRSS KuSA forward service signal acquisition by the customer platform and do not include operational procedures related to acquisition:

a. KuSAF Program Track and LEO Program Track Scenarios:

1. The TDRSS KuSA forward service signal does not depend on a customer platform return service.
2. Prior to the start of the TDRSS KuSA forward service, the TDRSS KuSA antenna will be open-loop pointed in the direction of the customer platform.
3. At the start of the TDRSS KuSA forward service as defined by the SHO, the TDRS will radiate, in the direction of the customer platform, a signal compatible with the TDRSS KuSA forward service signal parameters listed in Table 7-1. The EIRP directed towards the customer platform is dependent upon the customer providing an ephemeris uncertainty within the values defined in Table 7-2.

Table 7-3. Salient Characteristics for TDRSS KuSA Forward Services

Parameter (Note 1)	**Value** (Note 1)	
Command channel radiated power	QPSK	BPSK
Range channel radiated power	+10 ±0.5 dB	NA
Modulator phase imbalance (peak)	±3 degrees (for each BPSK channel)	
Modulator gain imbalance (peak)	±0.25 dB	
Relative phase between command and range channels	QPSK 90 ±3 degrees	BPSK NA
Data asymmetry (peak) (Note 2)	±3 percent	
Data rise time (90 percent of initial state to 90 percent of final state) (Note 2)	≤5 percent of bit duration	
Phase nonlinearity (peak)	±0.15 radian over ±17.5 MHz	
Gain flatness (peak)	±0.8 dB over ±17.5 MHz	
Gain slope (peak)	±0.1 dB/MHz	
AM/PM	≤7 degrees/dB	
PN chip jitter (rms) (including effects of Doppler compensation)	QPSK ≤1 degree	BPSK NA
Data bit jitter (peak) (Note 2)	≤1 percent	
Spurious PM (rms)	≤1 degree	
In-band spurious outputs	≥27 dBc	
Incidental AM (peak)	≤2 percent	
Phase noise (rms)		
1 Hz - 10 Hz	≤1.5 degrees	
10 Hz - 32 Hz	≤1.5 degrees	
32 Hz - 1 kHz	≤4 degrees	
1 kHz - 25 MHz	≤2 degrees	
	QPSK	BPSK
Command/range channel PN chip skew (peak)	≤0.01 chip	NA
PN chip asymmetry (peak)	≤0.01 chip	NA
PN chip rate (peak) (relative to absolute coherence with carrier rate)	≤0.01 chips/sec at PN code chip rate	NA

Table 7-3. Salient Characteristics for TDRSS KuSA Forward Services (cont'd)

Notes:

1. The definitions and descriptions of the salient characteristics are provided in Appendix E.
2. These values are the TDRSS contributions for data asymmetry, data transition time, and bit jitter, assuming perfect forward service data is provided to WSC. The actual contributions by the NISN data transport system are negligible compared to those contributed by the TDRSS, since WSC reclocks the data before it is processed by WSC into the forward service signal.

Table 7-4. KuSA Forward Service Real-Time Configuration Changes

Real-Time Configuration Changes	GCMR	OPM	Forward Service Signal Interruption
Customer Receiver Center Frequency	98/04	OPM 03	Yes
Doppler Compensation Inhibit	98/08	OPM 11	No
Doppler Compensation Reinitiation	98/04	OPM 03	No
Forward Service Reacquisition (note 1)	98/03	OPM 02	Yes
Forward Service Sweep Request (refer to Table 7-1)	98/05	OPM 04	Yes
Data Rate	98/04	OPM 03	No
Polarization	98/04	OPM 03	Yes
Initiation or termination of the command channel PN code (note 2)	98/04	OPM 03	No
Forward Service Normal/High Power Mode EIRP Change	98/06	OPM 06	No

Notes:

1. Forward service reacquisition is a TDRSS reinitiation of forward link service by applying a 1 MHz frequency offset for 3 seconds to the predicted customer receive frequency specified in the customer's service specification code (refer to paragraph 10.2.2).
2. Initiation of the command channel PN code enables the range channel. Termination of the command channel PN code disables the range channel.

4. The customer platform receiving system will search for and acquire the command channel PN code (if applicable) and carrier. Normally, a customer MOC will not be transmitting forward service data to the NISN data transport system until the forward service signal has been acquired by the customer platform and the acquisition verified by the customer MOC from customer platform return service telemetry. Some customer platforms may require that there be no data transitions during the signal acquisition process, while others may merely result in longer acquisition times.
5. For QPSK modulation, the customer platform receiving system will search for and acquire the range channel PN code upon acquisition of the command channel PN code and carrier.
6. Depending upon the customer platform receiving system design, upon completion of forward link acquisition and subsequent customer platform transition to signal tracking, the customer platform transmitting system may either switch to a coherent mode or remain in a noncoherent mode until commanded by the customer MOC to switch.
7. The WSC will continue Doppler compensation of the TDRSS KuSA forward service signal unless requested by the customer MOC to inhibit the Doppler compensation.
8. T_{acq} in the customer platform receiver is a function of the customer platform receiver design and signal-to-noise density ratio. The customer platform forward service acquisition time must be considered in determining the overall return service acquisition time for customer platform with a coherent mode of operation.
9. Appendix A provides example link calculations for the TDRSS KuSA forward service.

b. KuSAF Acquisition Scenario with Return Autotrack Services:

1. Prior to return autotrack acquisition, the TDRSS forward service EIRP will be the program or LEO program track high-power values, whichever is applicable based upon customer characteristics (see paragraph 7.2.5.a for a description of the program and LEO program track acquisition scenarios). The EIRP directed towards the customer platform is dependent upon the customer providing an ephemeris uncertainty within the values defined in Table 7-2. The appropriate TDRS KuSA autotrack normal-power or high-power mode signal EIRP listed in Table 7-2 will be provided after return service autotrack acquisition is achieved.

7.3 KuSA Return Services

7.3.1 General

The RF signals provided by the customer platform to the TDRS and the characteristics of data provided at the WSC interface are defined in paragraphs 7.3.2 through 7.3.5.

This discussion assumes that an appropriate return service has been scheduled and a data signal is present at the TDRS interface.

7.3.2 Signal Parameters

The TDRSS KuSA return service signal parameters are listed in Table 7-5. The services are divided into 2 major groups, Data Group 1 (DG1) and Data Group 2 (DG2). DG1 services utilize spread spectrum modulation while DG2 services are non-spread. A description of the features inherent in the DG1 and DG2 services is discussed in paragraphs 7.3.2.2 and 7.3.2.3, respectively. Within each data group, there are several types of modulation. Additionally, both data groups support coherent and noncoherent modes. A description of these general characteristics is provided in paragraph 7.3.2.1.

Table 7-5. TDRSS KuSA Return Service Signal Parameters

Parameter (Note 5)	**Description** (Note 5)
DG1 (note1)	
Transmit carrier frequency (Hz) (note 4)	F_1
Carrier (F1) reference (Hz)	
DG1 modes 1 and 3	$\left(\frac{1600}{1469}\right) \times F_R$
DG1 mode 2	Customer platform transmitter oscillator
PN code modulation	
DG1 modes 1 and 2	SQPN, or BPSK (see Appendix B and Table 7-6)
DG1 mode 3 I channel	PSK $\pm\pi/2$ radians
PN code chip rate (chips/sec)	$\left[\frac{31}{1600 \times 96}\right] \times F_1$
PN code length (chips)	
DG1 modes 1 and 3	$(2^{10}-1) \times 256$
DG1 mode 2	$2^{11}-1$
PN code epoch reference	
DG1 mode 1	
I channel	Epoch (all 1's condition) synchronized to epoch (all 1's condition) of received forward service range channel PN code
Q channel (note 3)	Epoch delayed x + 1/2 PN code chips relative to I channel PN code epoch
DG1 mode 2	Not Applicable
DG1 mode 3, I channel	Same as DG1 mode 1, I channel

Table 7-5. TDRSS KuSA Return Service Signal Parameters (cont'd)

Parameter (Note 5)	**Description** (Note 5)
DG1 (note 1)(cont)	
PN code family	
DG1 modes 1 and 3	Truncated 18-stage shift register sequences
DG1 mode 2	Gold codes
Data modulation	
DG1 modes 1 and 2	Modulo-2 added asynchronously to PN code
DG1 mode 3	
I channel	Modulo-2 added asynchronously to PN code
Q channel	PSK $\pm\pi/2$ radians
Data format	
Without convolutional encoding	NRZ-L, NRZ-M, NRZ-S, Bi∅-L, Bi∅-M, Bi∅-S
With convolutional encoding	NRZ-L, NRZ-M, NRZ-S
DG1 mode 1 data rate restrictions (uncoded)	
Total	1 - 600 kbps
I channel	1 - 300 kbps
Q channel	1 - 300 kbps
DG1 mode 2 data rate restrictions (uncoded)	
Total	1 - 600 kbps
I channel	1 - 300 kbps
Q channel	1 - 300 kbps
DG1 mode 3 data rate restrictions (uncoded)	
Total	I + Q
I channel	1 - 300 kbps
Q channel	1 kbps - 150 Mbps
DG1 $\frac{\text{Q channel power}}{\text{I channel power}}$ restrictions (note 2)	
Single data source-identical data	1:1 to 4:1
Single data source-single data channel	NA
Dual data sources	1:1 to 4:1

Table 7-5. TDRSS KuSA Return Service Signal Parameters (Cont'd)

Parameter (Note 5)	**Description** (Note 5)
DG2 (note 1)	
Transmit carrier frequency (Hz) (note 4)	F_2
Carrier (F_2) reference (Hz)	
DG2 Coherent	$\left(\frac{1600}{1469}\right) x F_R$
DG2 Noncoherent	Customer platform oscillator
Data modulation (note 1)	BPSK, SQPSK, or QPSK (refer to Appendix B and Table 7-6)
Data format	
Without convolutional encoding	NRZ-L, NRZ-M, NRZ-S, BiØ-L, BiØ-M, BiØ-S
With Rate 1/2 convolutional encoding	NRZ-L, NRZ-M, NRZ-S
Data rate restrictions (uncoded)	
Total (note 1)	1 kbps - 300 Mbps
I channel	1 kbps - 150 Mbps
Q channel	1 kbps - 150 Mbps
DG2 $\frac{\text{I channel power}}{\text{Q channel power}}$ restrictions	
Single data source-alternate I/Q bits	1:1
Single data source-alternate I/Q encoded symbols	1:1
Single data source-single data channel	NA
Dual data sources	1:1 to 4:1

Notes:

1. Customer platform data configurations, including specific data rate restrictions for coding and formatting, are defined in Table 7-6 for TDRSS KuSA return service (refer also to Appendix B). Unless otherwise stated, the data rate restrictions given in this table assume uncoded and NRZ formatted signals.
2. For DG1, the Q/I power parameter range can vary from 1:1 to 4:1 continuously during specification of applicable parameter values in the DSMC scheduling database and during real-time service reconfiguration. However if this parameter is respecified in schedule requests to the DSMC (refer to paragraph 10.2.2), it is expressed as the ratio of two single-digit integers.
3. The Q channel PN code sequence must be identical to the I channel PN code sequence; but, offset x + 1/2 PN code chips, where x $\geq$20,000. The value of x is defined by the PN code assignment for a particular customer platform (refer to 451-PN CODE-SNIP).
4. The center frequency, f_O, of the customer platform transmitter must be defined by the customer MOC in its service specification code to an integral multiple of 10 Hz.
5. Unless otherwise noted, all data rate values are to be interpreted as data bit rates, and not as data symbol rates.

7.3.2.1 General Modulation and Coherent/Noncoherent Description

a. SQPN Modulation. SQPN modulation is used to prevent simultaneous transitions of the I and Q PN sequences. For SQPN modulation, the PN chips of the I and Q channel are staggered by a 1/2 chip. For data configurations that use two PN spread channels, SQPN modulation must be used.

b. SQPSK Modulation. SQPSK modulation staggers one channel with respect to the other to prevent synchronous transitions. For non-spread signal configurations with identical I and Q symbol rates that are NRZ symbol formatted, SQPSK modulation must be used. The symbols of the Q channel are delayed 1/2 symbol relative to the I channel. For non-spread signal configurations that use biphase symbol formatting on either channel and the baud rate of the two channels are identical, SQPSK modulation is used and the transitions of one channel occur at the mid-point of adjacent transitions of the other channel.

c. QPSK Modulation. QPSK modulation is available when there is no relation between the I and Q channel transitions. For dual data source configurations, in which one or both channels are not spread and SQPSK is not required, QPSK modulation is used.

d. BPSK Modulation. BPSK modulation is available for single data source configurations that use only one channel of the link.

NOTES

For SQPN and SQPSK modulation, the spectral characteristics of a customer platform saturated power amplifier will, to a great degree, retain the spectral characteristics of the band-limited input signal to that amplifier. This should result in better control of out-of-band emissions, which, in turn, provides more efficient communications and less interference to customer platform using adjacent frequency channels on the TDRS links.

e. Coherent Mode. For coherent modes, the customer platform transmitted return link carrier frequency and PN code clock frequency (if applicable) are derived from the customer platform received forward link carrier frequency. For coherent PN spread return links, the customer return PN code length is identical to the length of the received forward service range channel PN code. The customer return I channel PN code epoch is synchronized with the epoch of the received forward service range channel PN code. For coherent operations, two-way Doppler measurements and range measurements (if PN spread) are available.

f. Noncoherent Mode. For noncoherent modes, the customer platform transmitted return link carrier frequency and PN code clock frequency (if applicable) are derived from an on-board local oscillator. The customer platform transmit frequency for noncoherent service must be defined by the customer MOC to an accuracy of ±5 kHz in its service specification code when requesting TDRSS KuSA return service. For customers whose frequency uncertainty is greater than ±5 kHz, an expanded frequency search capability is available.

g. Asynchronous Data Modulation. The data modulation is asynchronous to the carrier and the channel PN code (if applicable). This prevents Doppler variations of the forward service frequency from affecting the return service data rate.

7.3.2.2 DG1 Signal Parameters

DG1 signal parameters are subdivided into three modes of operation, DG1 modes 1, 2, and 3. For all DG1 modes, the PN code clock must be coherently related to the transmitted carrier frequency. This feature permits the customer platform transmitter to use a common source for generating the carrier and the PN code clock frequencies. 451-PN CODE-SNIP defines all the salient characteristics for the DG1 PN code libraries. The agency Spectrum Manager responsible for PN code assignments will allocate a customer platform-unique PN code assignment from these libraries. The GSFC Spectrum Manager is responsible for NASA PN code assignments. These three DG1 modes which are distinguished as follows:

a. DG1 Mode 1. DG1 mode 1 must be used when TDRSS range and two-way Doppler measurements (coherent transponder operations) are required concurrently with return service low-rate data transmission. Return service signal acquisition by the WSC for DG1 mode 1 is possible only when the scheduled TDRSS KuSA forward service signal is acquired by the customer platform and the PN code and carrier transmitted by the customer platform are coherently related to the forward service signal from the TDRS. If the TDRSS forward service signal becomes unavailable to the customer platform, the customer platform transmitter must switch to noncoherent transmitter operation (DG1 mode 2) (refer to paragraph 7.3.5.d.(2)). In order to reacquire the DG1 mode 2 signal, the return service must be reconfigured. The I and Q channel PN codes are generated from a single code generator. For DG1 mode 1 operation, the I and Q channel PN codes are identical but are offset by at least 20,000 chips. This separation is adequate for TDRSS to identify each data channel unambiguously without requiring a unique PN code for each channel.

b. DG1 Mode 2. DG1 mode 2 can be used when WSC return service signal acquisition is necessary without the requirement for prior customer platform signal acquisition of the TDRSS KuSA forward service (noncoherent transponder operation). The customer platform transmit frequency for DG1 mode 2 service must be defined by the customer MOC to an accuracy of ±5 kHz in its service specification code when requesting TDRSS KuSA return service. For customers whose frequency uncertainty is greater than ±5 kHz, an expanded frequency search capability of ±20 kHz is available after start of the return service. For DG1 mode 2, the I and Q channel PN codes are unique 2^{11}-1 Gold Codes.

c. DG1 Mode 3. DG1 mode 3 can be used when range and two-way Doppler measurements (coherent transponder operations) are required concurrently with return service high-rate data transmission. Restrictions on DG1 mode 3 signal acquisition are identical to those for DG1 mode 1. In Mode 3, the Q channel must contain only data and no PN code.

d. Functional Configurations. Table 7-6 lists the DG1 KuSA return service functional configurations and a further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in section B.3.2.

7.3.2.3 DG2 Signal Parameters

DG2 signal parameters are subdivided into two modes of operation, DG2 coherent and noncoherent. DG2 must be used when the return service data rate equipment exceeds the capability of DG1 operations. DG2 operations cannot provide TDRSS range tracking because PN code modulation is not used. The two DG2 modes are distinguished as follows:

a. DG2 Coherent. Return service signal acquisition by the WSC for DG2 coherent is possible only when the scheduled KuSA TDRSS forward service signal is acquired by the customer platform and the carrier transmitted by the customer platform are coherently related to the forward service signal from the TDRS. TDRSS two-way Doppler tracking can be provided when the DG2 carrier is coherently related to the TDRSS KuSA forward service carrier frequency.

b. DG2 Noncoherent. The DG2 carrier is independent of the TDRSS KuSA forward service carrier frequency. The customer platform transmit frequency for DG2 noncoherent service must be defined by the customer MOC to an accuracy of $\pm$5 kHz in its service specification code when requesting TDRSS KuSA return service. For customers whose frequency uncertainty is greater than $\pm$5 kHz, an expanded frequency search capability of $\pm$20 kHz is available after start of the return service.

c. Functional Configurations. Table 7-6 lists the DG2 KuSA return service functional configurations and a further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in section B.3.3.

Table 7-6. KuSA Return Service Configurations

Return Service Configuration[6]				Source Data Rate Restrictions and Availability[5]					
				DG1 Mode				DG2 Mode	
				1[1] and 2[1,4]		3[2]		Coherent[3] and Noncoherent[3,4]	
				Data format	Data rate	Data format	Data rate	Data format	Data rate
Single Data Source	BPSK	Rate 1/2 coded		NRZ	1 - 150 kbps[1]	-	-	NRZ	1 kbps – 75 Mbps
				NRZ with biphase symbols	1 - 75 kbps[1]			NRZ with biphase symbols	1 kbps – 5 Mbps
		Rate 1/3 coded		-	-	-	-	-	-
		Uncoded		NRZ	1 - 300 kbps[1]	-	-	NRZ	1 kbps – 150 Mbps
				Biphase	1 - 150 kbps[1]			Biphase	1 kbps – 5 Mbps
	SQPN	Identical I & Q channel data	Rate 1/2 coded	NRZ	1 - 150 kbps	-	-	-	-
				NRZ with biphase symbols	1 - 75 kbps				
			Uncoded	NRZ	1 - 300 kbps	-	-	-	-
				Biphase	1 - 150 kbps				
	SQPSK	Rate 1/2 coded alternate I/Q encoded symbols		-	-	-	-	NRZ	1 kbps – 10 Mbps
	SQPSK[3]	Alternating I/Q data	Individually rate 1/2 coded	-	-	-	-	NRZ	>10 – 150 Mbps
			Individually rate 1/3 coded	-	-	-	-	-	-
			Uncoded	-	-	-	-	NRZ	>10 – 300 Mbps

Table 7-6. KuSA Return Service Configurations (cont'd)

Return Service Configuration[6]			Source Data Rate Restrictions and Availability[5]					
			DG1 Mode				DG2 Mode	
			1[1] and 2[1,4]		3[2]		Coherent[3] and Noncoherent[3,4]	
			Data format	Data rate	Data format	Data rate	Data format	Data rate
Dual Data Sources (data rates are for each source separately)	SQPN[1], QPSK[2,3] or SQPSK[3]	Rate 1/2 coded	NRZ	1 - 150 kbps	NRZ	I: 1 - 150 kbps Q: 1 kbps – 75 Mbps	NRZ	1 kbps – 75 Mbps
			NRZ with biphase symbols	1 - 75 kbps	NRZ with biphase symbols	I: 1 - 75 kbps Q: 1 kbps – 5 Mbps	NRZ with biphase symbols	1 kbps – 5 Mbps
		Rate 1/3 coded	-	-	-	-	-	-
		Uncoded	NRZ	1 - 300 kbps	NRZ	I: 1 - 300 kbps Q: 1 kbps – 150 Mbps	NRZ	1 kbps – 150 Mbps
			Biphase	1 - 150 kbps	Biphase	I: 1 - 150 kbps Q: 1 kbps – 5 Mbps	Biphase	1 kbps – 5 Mbps

✓ Configuration supported

\- Configuration not supported

Notes:

1. For DG1 mode 1 and 2 configurations:
   a. For data on a single I or Q channel, but not both channels: BPSK modulation is used where the data is modulo-2 added to the PN code.
   b. For data on both the I and Q channels: SQPN modulation is used and the SN supports I:Q power ratios of 1:1 to 1:4.
2. For DG1 mode 3 configurations:
   a. The modulation is QPSK, where the I channel data is modulo-2 added to the PN code, and the Q channel data directly modulates the carrier at $+\pi/2$ radians.
   b. The SN supports I:Q power ratios of 1:1 to 1:4.
3. For DG2 configurations:
   a. For single data source configurations with data on one channel: BPSK modulation is used.
   b. For single data source configurations with data on both channels: SQPSK modulation and an I:Q power ratio of 1:1 is used. For the alternate I/Q bit configuration, the SN requires the I and Q channels be independently differentially formatted (-M,-S).
   c. For dual data source configurations: SQPSK must be used when there are identical baud rates on the I and Q channels (see paragraph 7.3.2.1.b); QPSK is used for all other configurations; for both SQPSK and QPSK, either an I:Q power ratio of 1:1 or 4:1 is supported. For unbalanced QPSK, the I channel must contain the higher data rate and when the data rate on the I channel exceeds 70 percent of the maximum allowable data rate, the Q channel data rate must not exceed 40 percent of the maximum allowable data rate on that Q channel.
4. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of $\pm$ 5 kHz. If a customer cannot accurately define their transmit frequency to within $\pm$ 5 kHz, a customer can request a reconfiguration which would expand the oscillator frequency search to $\pm$ 20 kHz after the start of service.
5. Unless otherwise noted, all data rates are to be interpreted as data bit rates, and not as data symbol rates. Refer to paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities.
6. Appendix B describes the functional configurations and associated I-Q channel and data polarity ambiguities. Additionally, Figure B-10 depicts the SN supported convolutional coding schemes. For a channel with rate 1/2 coding and data rates greater than 10 Mbps, the customer transmitter must be configured to use an N-parallel encoder, where N is the number of branch rate 1/2 encoders for the channel. N = channel data rate in bps/1×10^7, where N is rounded to the next higher integer if N is not an integer.

7.3.3 Communications Services

To obtain TDRSS KuSA return service performance defined in this paragraph, the customer platform transmitted signal must meet the requirements found in Table 7-7 and signal characteristics specified in Table 7-9. The TDRSS KuSA return service performance defined in this paragraph also assumes return service operation in an AWGN environment. Appendix G discusses performance degradations to the TDRSS KuSA return service due to RFI. Example link calculations are provided in Appendix A. TDRSS KuSAR supports only supports non-powered flight customer dynamics ($\dot{R} \leq$ 12 km/sec, $\ddot{R} \leq$ 15 m/sec^2, and $\dddot{R} \leq$ 0.02 m/sec^3).

7.3.3.1 Acquisition

The KuSAR service supports acquisition for customer platforms operating under non-powered flight dynamics as defined in paragraph 7.3.3. KuSAR acquisition will be protected against false WSC lock to: interfering customer platform PN codes, customer platform PN code sidelobes, and carrier recovery. The KuSAR service total channel acquisition times (T_{acq}) are given in Table 7-7 and are the sum of the following:

a. Autotrack acquisition time (when the TDRSS KuSA return service autotrack mode is enabled)

b. PN (DG1 only) and carrier acquisition time

c. Symbol/Decoder synchronization time (for coded data) or Symbol synchronization time (for uncoded data).

T_{acq} assumes that the customer platform return service signal is present at the WSC at the start time of the scheduled return service support period and the process is described below.

a. If autotrack is enabled, autotrack acquisition will commence upon the start of the scheduled return service support period.

b. PN code (if applicable) and carrier acquisition will commence upon autotrack acquisition (if applicable) or upon the start of the scheduled return service support period (if autotrack is disabled).

c. After PN code (if applicable) and carrier acquisition is achieved, TDRSS tracking services data is available.

d. Symbol/Decoder and Symbol synchronization times will be measured from the time carrier acquisition is achieved to the time either symbol synchronization is achieved for uncoded channels or decoder synchronization is achieved for rate 1/2 coded channels. Decoder synchronization is achieved when the Viterbi decoder has selected and implemented the correct blocking of the input symbols (into groups of (G1,G2) symbol pairs) for rate 1/2 codes.

Table 7-7. TDRSS KuSA Return Service

Parameter (Note 4)	**Description** (Note 4)		
Field of view (FOV) (each TDRS)	Primary (PFOV) $\pm$ 22 degrees east-west $\pm$ 28 degrees north-south (rectangular)	LEO (LEOFOV) $\pm$10.5 degree conical	Extended Elliptical (EEFOV) (F8-F10) (note 10) 24.0 degrees inboard east-west 76.8 degrees outboard east-west $\pm$30.5 degrees north-south
Customer Ephemeris Uncertainty (along the customer orbital track)	$\le \pm$ 4.5 sec	$\le \pm$ 1.5 sec	$\le \pm$ 3.2 sec
TDRS antenna polarization (note 1)	RHC or LHC selectable		
TDRS antenna axial ratio (maximum) (note 9)	After Autotrack Acquisition (PFOV, LEOFOV, and EEFOV) (notes 10, 12) 1 dB over 3 dB beamwidth	LEO Program Track (LEOFOV) 1 dB over 3-dB beamwidth	Program Track (PFOV and EEFOV) 1.5 dB
Receive frequency (nominal)	$\left(\frac{1600}{1469}\right)\times 13.775\ \text{GHz} \pm 0.7\ \text{MHz}$		
RF bandwidth (3dB, minimum)	225 MHz		
10^{-5} Bit Error Rate (notes 2, 3, 4, 8)	All P_{rec} values are in dBW; dr=data rate in bps		
Orbital Dynamics (free flight)	$\dot{R} \le 12\ \text{km/sec}, \ddot{R} \le 15\ \text{m/sec}^2$, jerk $\le .02\ \text{m/sec}^3$		
Minimum Required P_{rec} (dBW) for uncoded channels (note 9):	Autotrack (PFOV, LEOFOV, and EEFOV) (notes 10, 12)	LEO Program Track (LEOFOV)	Program Track (PFOV and EEFOV)
DG1, modes 1 and 2	-240.0. + $10\log_{10}$(dr)	-237.5 + $10\log_{10}$(dr)	-234.0 + $10\log_{10}$(dr)
DG1, mode 3			
I channel	$\ge$ -183.3 dBW (note 3)	$\ge$ -180.8 dBW (note 3)	$\ge$ -177.3 dBW (note 3)

Table 7-7. TDRSS KuSA Return Service (Cont'd)

Parameter (Note 4)	**Description** (Note 4)		
10^{-5} Bit Error Rate (notes 2, 3, 4, 8) (cont'd):			
Minimum Required P_{rec} (dBW) for uncoded channels (cont'd) (note 9):	Autotrack (PFOV, LEOFOV, and EEFOV) (notes 10, 12)	LEO Program Track (LEOFOV)	Program Track (PFOV and EEFOV)
DG1, mode 3			
Q channel			
Data rate $\leq$ 25 Mbps	$-240.0 + 10\log_{10}(dr)$	$-237.5 + 10\log_{10}(dr)$	$-234.0 + 10\log_{10}(dr)$
Data rate > 25 Mbps (F1-F7) (note 11)	$-237.9 + 10\log_{10}(dr)$	$-235.4 + 10\log_{10}(dr)$	$-231.9 + 10\log_{10}(dr)$
Data rate > 25 Mbps (F8-F10)	$-239.0 + 10\log_{10}(dr)$	$-236.5 + 10\log_{10}(dr)$	$-233.0 + 10\log_{10}(dr)$
DG2			
Data rate $\leq$ 25 Mbps	$-240.0 + 10\log_{10}(dr)$	$-237.5 + 10\log_{10}(dr)$	$-234.0 + 10\log_{10}(dr)$
Data rate > 25 Mbps (F1-F7) (note 11)	$-237.9 + 10\log_{10}(dr)$	$-235.4 + 10\log_{10}(dr)$	$-231.9 + 10\log_{10}(dr)$
Data rate > 25 Mbps (F8-F10)	$-239.0 + 10\log_{10}(dr)$	$-236.5 + 10\log_{10}(dr)$	$-233.0 + 10\log_{10}(dr)$
Minimum Required P_{rec} (dBW) for Rate 1/2 convolutional encoded channels (note 9):			
DG1, modes 1 and 2	$\geq$ -183.3 dBW (note 3)	$\geq$ -180.8 dBW (note 3)	$\geq$ -177.3 dBW (note 3)
DG1, mode 3			
I channel	$\geq$ -183.3 dBW (note 3)	$\geq$ -180.8 dBW (note 3)	$\geq$ -177.3 dBW (note 3)
Q channel			
Data rate $\leq$ 10 Mbps	$-246.4 + 10\log_{10}(dr)$	$-243.9 + 10\log_{10}(dr)$	$-240.4 + 10\log_{10}(dr)$
Data rate > 10 Mbps	$-245.2 + 10\log_{10}(dr)$	$-242.7 + 10\log_{10}(dr)$	$-239.2 + 10\log_{10}(dr)$

Table 7-7. TDRSS KuSA Return Service (Cont'd)

Parameter (Note 4)	**Description** (Note 4)		
10^{-5} Bit Error Rate (notes 2, 3, 4, 8) (cont'd): Minimum Required P_{rec} (dBW) for Rate 1/2 convolutional encoded channels (note 9) (cont'd):	Autotrack (PFOV, LEOFOV, and EEFOV) (notes 10, 12)	LEO Program Track (LEOFOV)	Program Track (PFOV and EEFOV)
DG2			
Data rate ≤ 10 Mbps	$-246.4 + 10\log_{10}(dr)$	$-243.9 + 10\log_{10}(dr)$	$-240.4 + 10\log_{10}(dr)$
Data rate > 10 Mbps	$-245.2 + 10\log_{10}(dr)$	$-242.7 + 10\log_{10}(dr)$	$-239.2 + 10\log_{10}(dr)$
Acquisition (notes 5, 8):			
Orbital dynamics (free flight)	$\dot{R} \leq 12$ km/sec, $\ddot{R} \leq 15$ m/sec^2, jerk $\leq .02$ m/sec^3		
Total Channel Acquisition Time (assumes the customer return service signal is present at the WSC at the start time of the return service support period)	Sum of the following: 1. Autotrack acquisition time (when the TDRSS KuSA return service autotrack mode is enabled) 2. PN (DG1 only) and carrier acquisition time 3. Symbol/Decoder synchronization time (coded channel) or Symbol synchronization time (uncoded channel)		
Autotrack Acquisition (if applicable): Minimum Required P_{rec} with probability > 99% (notes 9, 12)	PFOV ≥-183.3 dBW or consistent with the P_{rec} for BER, whichever is greater	LEOFOV ≥-186.8 dBW or consistent with the P_{rec} for BER, whichever is greater	EEFOV (note 10) ≥-183.3 dBW or consistent with the P_{rec} for BER, whichever is greater
Acquisition Time:	≤ 10 seconds		

Table 7-7. TDRSS KuSA Return Service (Cont'd)

Parameter (Note 4)	**Description** (Note 4)		
Acquisition (notes 5, 8) (cont'd):			
PN Code (if applicable) and Carrier Acquisition:			
Minimum Required P_{rec} (note 9)	Autotrack (PFOV, LEOFOV, and EEFOV) (notes 10, 12) $\geq$ -183.3 dBW or consistent with the P_{rec} for BER, whichever is greater	LEO Program Track (LEOFOV) $\geq$ -180.8 dBW or consistent with the P_{rec} for BER, whichever is greater	Program Track (PFOV and EEFOV) $\geq$ -177.3 dBW or consistent with the P_{rec} for BER, whichever is greater
Acquisition Time ($P_{acq} \geq$ 90%)			
Coherent operations	$\leq$ 1 sec		
Noncoherent operations with frequency uncertainty (note 6):			
$\leq \pm$ 5 kHz	$\leq$ 1 sec		
$\leq \pm$ 20 kHz	$\leq$ 3 sec		
Channel Decoder/Symbol Synchronization Acquisition (coded data) (note 7):			
Minimum data bit transition density	$\geq$ 64 randomly distributed data bit transitions within any sequence of 512 data bits		
Number of consecutive data bits without a transition	$\leq$ 64		
P_{rec} (dBW)	consistent with the P_{rec} for BER		
Acquisition time (in seconds) with >99% probability:			
Biphase NRZ	< 1100/(Channel Data Rate in bps) < 6500/(Channel Data Rate in bps)		

Table 7-7. TDRSS KuSA Return Service (Cont'd)

Parameter (Note 4)	**Description** (Note 4)
Acquisition (notes 5, 8) (cont'd):	
Channel Symbol Synchronization Acquisition (uncoded data) (note 7):	
P_{rec} (dBW)	consistent with the P_{rec} for BER
Synchronization	Achieved when error rate for next 1000 bits is $\leq 10^{-5}$
Acquisition time (in seconds) with >99% probability:	
Biphase NRZ	< 300/(Channel Data Rate in bps) < 3000/(Channel Data Rate in bps)
Signal Tracking	refer to paragraph 7.3.3.3
Orbital dynamics (free flight)	$\dot{R} \leq 12$ km/sec, $\ddot{R} \leq 15$ m/sec^2, jerk $\leq .02$ m/sec^3
Reacquisition	refer to paragraph 7.3.3.4
Orbital dynamics (free flight)	$\dot{R} \leq 12$ km/sec, $\ddot{R} \leq 15$ m/sec^2, jerk $\leq .02$ m/sec^3
Duty Factor	100 percent

Notes:

1. Operational considerations may limit choice of TDRS antenna polarization. The KuSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.
2. The BER is for a customer platform transmitting a signal on an AWGN channel which complies with the constraints defined in Table 7-9. Refer to Appendix G for a discussion of the additional degradation applicable to the TDRSS KuSA return service performance due to K-band RFI.

Table 7-7. TDRSS KuSA Return Service (Cont'd)

Notes (cont'd):

3. The required customer P_{rec} must meet the P_{rec} for BER, autotrack acquisition, or signal acquisition, whichever is greatest. Paragraph 7.3.3.2.b provides the required P_{rec} description for each possible KuSAR data configuration. Refer to Appendix A, paragraph A.4, for a definition of P_{rec}. The minimum required P_{rec} equations for BER produce the minimum P_{rec} for a given data rate for all possible signal characteristics. CLASS analysis will produce a more accurate performance projection based upon desired customer signal characteristics, such as data rate, data type, and jitter values. SN support may be possible for customers whose P_{rec} is less than the required P_{rec} for 10^{-5} BER performance as long as the customer is willing to accept support on a best-effort basis and less than 100 percent coverage. Any customer interested in receiving this marginal SN coverage shall be required to negotiate all support with the GSFC MSP. In general, customer platforms should be designed to the most limiting TDRS to ensure SN support can be provided.
4. All data rate values (and notes which modify these values, based upon specific signal format and encoding restrictions) are to be interpreted as data bit rates, and not as data symbol rates.
5. For acquisition, the minimum P_{rec} value listed applies to the total (I+Q)P_{rec}. Acquisition requires the P_{rec} to also be consistent with the P_{rec} required for BER, whichever is greater. Failure to provide the minimum P_{rec} for autotrack acquisition at the start of service may preclude successful TDRSS autotrack pullin.
6. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of $\pm$ 5 kHz. If a customer cannot accurately define their transmit frequency to within $\pm$ 5 kHz, a customer can request a reconfiguration which would expand the oscillator frequency search to $\pm$ 20 kHz after the start of service.
7. For symbol synchronization and symbol/decoder synchronization, the minimum symbol transition density and consecutive symbols without a transition must meet the specifications defined in Table 7-9. For encoded channels, it is recommended that customers use G_2 inversion to increase symbol transition density. Additionally, biphase symbol formatting increases symbol transition density.
8. All minimum P_{rec} values include atmospheric and rain attenuation on the link from TDRS to WSC; however, service outages may be experienced during periods of heavy rain.
9. The required P_{rec} for autotrack performance is based upon a customer meeting the required ephemeris uncertainties for the Primary FOV, LEOFOV, or the Extended Elliptical FOV. The required P_{rec} for program track performance is based upon a customer meeting the required ephemeris uncertainties for the Primary FOV or the Extended Elliptical FOV. The required P_{rec} for LEO program track performance is based upon a customer meeting the required LEO ephemeris uncertainties for the LEO FOV. Customers may experience better performance through the KuSA program track and LEO program track services than listed in this document. Performance improvements particular to each customer should be discussed with the GSFC MSP.
10. KuSA return autotrack service for the Extended Elliptical FOV will be supported on a best effort basis.
11. For KuSA DG1 mode 3 Q channel uncoded and DG2 uncoded services, the required P_{rec} values for support through GRGT are only valid up to a total(I+Q) data rate of 150 Mbps. If higher data rates are required through GRGT, contact the GSFC MSP for detailed calculations and use of dedicated service.
12. The KuSA autotrack service can experience longer outages due to RFI as the SA antenna will track the interfering signal rather than the desired signal. Additionally, the KuSA autotrack system can occasionally "wander" during signal fade or no RF conditions, which can cause a delay in acquisition after the signal is restored to its proper level.

e. After symbol/decoder and symbol synchronization is achieved, KuSA return service channel data is available at the WSC interface.

f. To minimize return data loss, it is recommended that the customer platform transmit idle pattern on its data channels until after it has observed (via the UPD data) that the WSC has completed all of its data channel signal acquisition processes.

g. Requirements for bit error probability and symbol slipping take effect at the time decoder synchronization is achieved for convolutional encoded data and at the time symbol synchronization is achieved for uncoded data.

NOTE

Data and symbol transition densities values higher than the minimums required will reduce these acquisition times.

7.3.3.2 Bit Error Rate (BER)

Table 7-7 provides P_{rec} equations that will result in a customer achieving a BER of 10^{-5} for TDRSS compatible signals. The BER P_{rec} equations are applicable for non-powered flight dynamics and the following conditions:

a. Data encoding. Customer platform transmission of Rate 1/2 convolutional encoded or uncoded signals are supported for KuSA return services. Detailed rate 1/2 coding design is described in Appendix B. Reed-Solomon decoding is available to WDISC customers; typical performance is given in Appendix K.

b. Received Power. P_{rec} is in units of dBW. The customer project, in determining its design requirements for minimum customer platform EIRP, must take into account customer platform transmit antenna pointing losses, the space loss between the customer platform and the TDRS, and the polarization loss incurred between the customer platform transmit antenna and the TDRS receive antenna. The maximum TDRS receive antenna axial ratio is given in Table 7-7 (also refer to Appendix A). For DG1 and DG2 services, the following conditions apply:

    1. Balanced Power Single Data Source-Identical Data on the I and Q Channels (DG1 mode 1 and 2 only). For a customer platform synchronously transmitting identical data on the I and Q channels (single data source-identical data) with a balanced I and Q channel power division, the total (I+Q) P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 7-7, where dr is the single data source data rate. Refer to Appendix B for further information on this data configuration.

    2. Balanced Power Single Data Source-Alternate I/Q Bits (DG2). For a customer platform transmitting alternate I and Q data bits from a

data source (single data source-alternate I/Q bits), the total (I+Q)P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 7-7, where dr is the single data source data rate prior to separation into the I and Q channels. The Q/I (power) must be equal to 1:1. Refer to Appendix B for further information on this data configuration.

3. Balanced Power Single Data Source-Alternate I/Q Encoded Symbols (DG2 only). For a customer platform transmitting alternate I and Q encoded symbols from a data source (single data source-alternate I/Q encoded symbols), the total (I+Q)P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 7-7, where dr is the single data source data rate prior to the rate 1/2 encoder. The Q/I (power) must be equal to 1:1. Refer to Appendix B for further information on this data configuration.

4. Unbalanced Power Single Data Source-Identical Data on the I and Q Channels (DG1 mode 1 and 2). For a customer platform synchronously transmitting identical data on the I and Q channels (single data source-identical data) having unbalanced I and Q channel power division, the stronger power channel P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 7-7, where dr is the single data source data rate. The weak channel P_{rec} need not be consistent with the P_{rec} for a 10^{-5} BER listed in Table 7-7. The Q/I (power) must not exceed 4:1. Refer to Appendix B for further information on this data configuration.

5. Dual Data Sources (DG1 and DG2). For a customer platform transmitting independent data on the I and Q channels (dual data sources), each channel's P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 7-7, where dr is that channel's data rate. Refer to Appendix B for further information on this data configuration.

6. Single Data Source with Single Data Channel (DG1 modes 1 and 2 and DG2). For a customer platform transmitting one channel, the channel's P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 7-7, where dr is the channel data rate. Refer to Appendix B for further information on this data configuration.

c. Customer Degradations. Further reductions in the TDRSS KuSA return service performance identified in Table 7-7 can occur. The TDRSS KuSA return services and tracking services will be provided without degradation for customer platform transmitted signal characteristics within the constraints specified in Table 7-9. Customer platform parameters exceeding these constraints can also degrade TDRSS KuSA return service performance. Refer to paragraph 3.5 for guidelines if the constraints in this paragraph cannot be met. Definitions of customer platform constraints are given in Appendix E.

d. Multipath. The WSC will provide lockup and interference protection from multipath signals reflected from the Earth.

7.3.3.3 Signal Tracking

TDRSS provides KuSA return signal tracking (carrier, PN, symbol synchronization, Viterbi decoder synchronization) for non-powered flight dynamics. During a customer KuSA return service support period, loss-of-lock (carrier, symbol synchronization, and Viterbi decoder) indications appear in the periodically updated User Performance Data (UPD) (every 5 seconds). The KuSA return service shall maintain signal tracking for the following conditions:

a. Cycle Slips. The mean time-between-cycle slip in the WSC carrier tracking loop for each TDRSS KuSA return service will be 90 minutes minimum. This value applies at carrier tracking threshold, which is 3 dB less than the minimum P_{rec} for BER listed in Table 7-7, and increases exponentially as a function of linear dB increases in P_{rec}. Cycle slips may result in channel and/or data polarity reversal. WSC can correct for these reversals under the same conditions as WSC can resolve channel and/or data polarity ambiguity as discussed in Appendix B. The time for the WSC to recover from a cycle slip will be consistent with the time required for the WSC receiver to detect and automatically reacquire the signal.

b. Bit Slippage. For each TDRSS KuSA return service operating with a minimum P_{rec} required consistent with the P_{rec} for BER of Table 7-7 and data transition densities greater than 40% for NRZ symbols or any transition density for biphase symbols, the minimum mean time between slips caused by a cycle slip in the WSC symbol clock recovery loop is either 90 minutes or 10^{10} symbol periods, whichever is greater. For a KuSA return service operating with 1 dB more than the minimum P_{rec} required for the BER, and NRZ symbol transition densities between 25% and 40%, the minimum mean time between slips is either 90 minutes or 10^{10} symbol periods, whichever is greater.

c. Loss of Symbol Synchronization. For each TDRSS KuSA return service with data transition densities greater than 40% for NRZ symbols and any transition density for biphase symbols, the WSC symbol synchronization loop will not unlock for a P_{rec} that is 3 dB less than the minimum P_{rec} required for BER in Table 7-7 (refer also to note 3 of Table 7-7). For NRZ symbol transition densities between 25% and 40%, the WSC symbol synchronizer loop will not unlock for a P_{rec} that is 2 dB less than the minimum P_{rec} required for BER. In both cases, the BER performance will be degraded when the P_{rec} is less than the minimum required for BER.

d. Loss of Autotrack. Loss of autotrack is detected by WSC when either:

1. The autotrack SA antenna azimuth/elevation angles diverge from the program track SA antenna azimuth/elevation angles. The check on angle divergence protects the autotrack system from false tracking an interfering signal. When loss of autotrack is detected due to angle divergence, WSC will automatically begin the autotrack acquisition process.
2. There is a drop in received power to a level that is 3 dB less than the minimum P_{rec} for BER. This ensures that the autotrack system does not cause an increase in pointing error due to return signal fades.
   (a) When loss of autotrack is detected due to signal fades during TDRS F1-F7 KuSAR support, WSC will revert to return program track, transmit a forward link signal towards a customer using the high power program track EIRP values listed in Table 7-2 (if forward service is scheduled), and automatically begin the return autotrack acquisition process.
   (b) For a maximum of 60 seconds after the first loss of autotrack is detected due to signal fades during TDRS F8-F10 KuSAR support, the TDRS SA antenna will continue to move at the calculated customer platform angular rate. If, within that 60 seconds, the KuSA return service P_{rec} has increased back to or above the minimum level required by the TDRSS KuSA return PN code/carrier acquisition, the process should transfer almost immediately to its fine-track mode as the TDRS SA antenna boresight should still be pointed fairly close to the actual direction of the customer platform position. However, if after 60 seconds the KuSA return service P_{rec} has not increased back to or above the minimum level required by the TDRSS KuSA return service PN code/carrier acquisition, the WSC reverts to open-loop pointing (program track) the TDRS SA antenna in the calculated direction of the customer platform position. When the WSC reverts to program track, the TDRSS will transmit a forward link signal towards a customer using the high power program track EIRP values listed in Table 7-2 (if forward service is scheduled). The TDRSS KuSA return service autotrack process will not restart until the KuSA return service P_{rec} has increased back to or above the minimum level required by that process.

7.3.3.4 Reacquisition

For return service autotrack reacquisition process, refer to paragraph 7.3.3.3.d. While in the PN/carrier tracking state, a loss of lock condition induced by a cycle slip will be automatically detected and a reacquisition will be automatically initiated. For a customer platform that continues to transmit the minimum P_{rec} for acquisition and maintains an ephemeris uncertainty as defined in Table 7-7, the normal total channel reacquisition time for non-powered flight dynamics will be less than or equal to that for the initial total channel acquisition, with a probability of at least 0.99. If lock is not achieved within 10 seconds of loss of lock, an acquisition failure notification message will be sent to the MOC and WSC will reinitiate the initial service acquisition process. Upon receipt of the loss-of-lock indications in the UPD, the customer MOC may request a TDRSS KuSA return service reacquisition GCMR (refer to section 10). It is recommended that the customer MOC delay initiation of the GCMR for at least 35 seconds after initial receipt of the loss-of-lock indications in the UPD.

7.3.3.5 Additional Service Restrictions

a. Sun Interference. The TDRSS KuSA return service performance will not be guaranteed when the center of the sun is within 1 degree of the TDRS KuSA receiving antenna boresight. Additionally, the TDRSS KuSA return service performance will not be guaranteed when the center of the sun is within 1 degree of the boresight of the WSC receiving antenna supporting the TDRS.

b. Mutual Interference. It is possible for mutual interference to exist between KuSA customer platforms operating with the same polarization. The SN can provide tools to assist customers in interference prediction and interference mitigation.

7.3.4 Real-Time Configuration Changes

Changes to the operating conditions or configuration of a TDRSS KuSA return service during a scheduled service support period are initiated by a GCMR from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the GCMR at the WSC. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning WSC response times for GCMRs is provided in section 10. Table 7-8 lists the KuSA return service real-time configuration changes and their effects on the return service.

7.3.5 Autotrack/Signal Acquisition Scenarios

The following acquisition scenario identifies only the technical aspects of TDRSS KuSA return service autotrack (if enabled) and signal acquisition by the WSC and does not include operational procedures related to acquisition. Acquisition is dependent upon the customer providing an ephemeris with a maximum epoch uncertainty as defined in Table 7-7:

Table 7-8. KuSA Return Service Real-Time Configuration Changes

Real-Time Configuration Changes	GCMR	OPM	Return Service Interruption
Return Service Reacquisition	98/03	OPM 03	Yes
Noncoherent Expanded Customer Spacecraft Frequency Uncertainty	98/07	OPM 07	No
Channel Data Rate	98/04	OPM 03	No
Noncoherent Transmit Frequency	98/04	OPM 03	Yes
Redefinition of minimum customer EIRP	98/04	OPM 03	Yes
Redefinition of maximum customer EIRP	98/04	OPM 03	No
I/Q Power Ratio	98/04	OPM 03	Yes
Channel Data Format	98/04	OPM 03	No
Channel Data Bit Jitter	98/04	OPM 03	No
DG1 Mode	98/04	OPM 03	Yes
Polarization	98/04	OPM 03	No
Data Group	98/04	OPM 03	Yes
DG2 Coherency	98/04	OPM 03	Yes
DG2 Carrier Modulation	98/04	OPM 03	Yes
TDRSS Autotrack Mode	98/04	OPM 03	No
Data Source/Channel Configuration	98/04	OPM 03	Yes
G_2 inversion	98/04	OPM 03	No
Frame Length	98/04	OPM 03	No
Frame Sync Word Length	98/04	OPM 03	No
Frame Sync Word Bit Pattern	98/04	OPM 03	No
Sync Strategy Parameters	98/04	OPM 03	No
Note: Items that are indicated to cause return service interruption will cause the WSC receiver to discontinue signal tracking and attempt to reacquire the return service signal after the appropriate reconfiguration. Additionally, any reconfigurations to the forward that cause forward link interruption will also cause return interruption for coherent return links. Any other reconfigurations of the WSC may momentarily affect signal tracking.			

a. TDRS SA Antenna Pointing:

1. KuSA Autotrack Description. The TDRSS KuSA return service autotrack process (if enabled) will acquire and track a customer platform KuSA return service signal providing a improved pointing of the TDRS SA antenna in the direction of the customer platform. This decreases the required P_{rec} at the input to the TDRS antenna. TDRSS KuSA return autotrack service is independent of whether the return signal is coherent or noncoherent relative to a TDRSS KuSA forward service signal or whether a TDRS forward service signal is concurrently scheduled.

2. Autotrack Power Requirement. For the TDRSS KuSA return service autotrack process to acquire a customer platform signal, the KuSA return service Prec must be consistent with either the P_{rec} required for autotrack acquisition or the Prec required for BER, whichever is greater (refer to Table 7-7).

3. Program track Operational Process. The WSC open-loop points the TDRS SA antenna in the calculated direction of the customer platform. The acquisition process begins with PN/carrier acquisition as described below for coherent or noncoherent operations as applicable.

4. Autotrack Operational Process. The WSC initially open-loop points the TDRS SA antenna in the calculated direction of the customer platform. If the TDRSS KuSA return service autotrack process is initiated (or reinitiated), the WSC then processes error signals derived from the received customer platform KuSA return service signal to correct for small error build-ups in moving the TDRS antenna at the calculated angular rate of the customer platform. After the time when the signal is first present at the TDRS with adequate KuSA return service P_{rec} [refer to paragraph (2)], autotrack acquisition will be achieved within the autotrack acquisition time listed in Table 7-7. The acquisition process continues with PN/carrier acquisition as described below for coherent or noncoherent operations as applicable.

5. TDRS Forward EIRP Level. If the TDRSS KuSA return service autotrack process is enabled, the forward service EIRP will default to high power program track values listed in Table 7-2 during autotrack acquisition. Following the completion of return autotrack acquisition, the forward EIRP will be consistent with the autotrack normal or high power values listed in Table 7-2. If the return autotrack service experiences a reacquisition, the forward EIRP values may decrease to the high power program track values. If the TDRSS KuSA return service autotrack process is inhibited, the forward EIRP will be consistent with the normal power or high power program track values listed in Table 7-2, where either LEO

program track or program track values depend upon customer platform orbital characteristics.

6. Interference Mitigation to S-band Customers. An instantaneous P_{rec} increase in the TDRSS KuSA return service channel being supported via the TDRS composite downlink Traveling Wave Tube Amplifier (TWTA) can potentially cause BER degradations to TDRSS SSA return services being concurrently supported via that same TDRS. For a customer platform KuSA return service signal that results in a P_{rec} greater than -159.2 dBW, it is recommended that the customer MOC plan to use the following operational procedure to minimize return service performance degradations to other ongoing customer platform missions due to an instantaneous increase in Ku-band P_{rec} level caused either by its customer platform signal being present at, or prior to, T_R (the time the return service begins) or by its customer platform turning on its transmitting system at, or subsequent to, T_R:

   (a) Prior to T_R: The P_{rec} (resulting from the customer platform KuSA return service signal level) must be less than -159.2 dBW. The instantaneous rate of change of P_{rec} need not be less than or equal to 10 dB/sec.

   (b) At, or subsequent to T_R: During the time period from T_R to the time that the P_{rec} (resulting from the customer platform KuSA return service signal level) reaches its scheduled initial value, the instantaneous rate of change of P_{rec} from T_R to that time should be less than or equal to 10 dB/sec (e.g., by initially causing the customer platform KuSA antenna to be off-pointed from the calculated direction of the TDRS at T_R and then slewing it at an appropriate rate, starting at T_R, to where it is pointing in the calculated direction of the TDRS).

b. Coherent Signal Acquisition Scenarios (DG1 Modes 1 or 3 and DG2 Coherent):

   1. For optimal TDRSS performance, all coherent services should have the TDRSS forward and return services starting at the same time. If operational considerations require starting the TDRSS forward service before the return service, no reconfigurations of the forward service can be sent within 30 seconds of the start of the return service. A forward link sweep request OPM cannot be sent within 150 seconds of the start of the return service.

   2. The customer platform P_{rec} must be compatible with the minimum P_{rec} required for BER and the other TDRSS KuSA return service signal parameters listed in Table 7-5.

   3. At the service start time specified by the SHO, the WSC will begin the search for the customer platform signal based upon predicted range and Doppler. The WSC corrects the received customer

platform signal for Doppler to allow for WSC implementation of receivers with narrow acquisition and tracking bandwidths. The Doppler correction used by WSC is either one-way (Forward Doppler compensation enabled) or two-way (Forward Doppler compensation inhibited). For coherent operation, the Doppler correction is based upon the forward service frequency.

4. After the forward service has been acquired and the P_{rec} is consistent with minimum P_{rec} required for BER, WSC will begin PN/carrier acquisition. PN/carrier acquisition may occur prior to completion of autotrack acquisition (if enabled). The WSC will acquire the customer platform signal (PN code (applicable to DG1 only) and carrier) within the time limits listed in Table 7-7. Return service will be achieved at the WSC receiver output within the total channel acquisition time limits listed in Table 7-7, which includes WSC symbol and Viterbi decoder (if applicable) synchronization.

c. Noncoherent (DG1 Mode 2 and DG2 Noncoherent):

1. This mode of customer platform operation does not require a TDRSS forward service signal to be received by the customer platform. However, the customer platform transmitter must be commanded to turn on when noncoherent transmissions are desired, either by stored commands, on-board configuration settings, or direct commands from its customer MOC.

2. The customer platform P_{rec} must be compatible with the minimum P_{rec} required for BER and the other TDRSS KuSA return service signal parameters listed in Table 7-5.

3. At the service start time specified by the SHO, the WSC will begin the search for the customer platform signal based upon predicted Doppler. The WSC corrects the received customer platform signal for Doppler to allow for WSC implementation of receivers with narrow acquisition and tracking bandwidths. The Doppler correction used by WSC is one-way and based on the customer platform transmission frequency stated in the SHO and any subsequent OPMs.

4. WSC will begin PN/carrier acquisition when the P_{rec} meets the minimum required value for this acquisition process. PN/carrier acquisition may occur prior to completion of autotrack acquisition (if enabled). The WSC will complete acquisition of the customer platform signal (PN code (applicable to DG1 only) and carrier) within the time limits listed in Table 7-7. Return service will be achieved at the WSC receiver output within the total acquisition time limits listed in Table 7-7, which includes WSC symbol and Viterbi decoder synchronization.

d. DG1 Mode Transitions:

1. DG1 Mode 2 to DG1 Mode 1 (or 3) Transitions. A TDRSS KuSA forward service must be scheduled to be established prior to customer MOC transmission of the GCMR to reconfigure the TDRSS for DG1 mode 1 (or 3) operations (refer to paragraph 7.3.5.b.(1)).
2. DG1 Mode 1 (or 3) to DG1 Mode 2 Transitions. When the customer platform switches to the noncoherent mode (DG1 mode 2), customer platform return service signal parameters (e.g., carrier and channel PN codes) are changed causing the WSC to drop TDRSS KuSA return service signal lock. Customer platform transponders designed to automatically switch from a coherent transponder mode to a noncoherent mode when the TDRSS KuSA forward service signal is lost will result in WSC loss of KuSA return service signal lock. Reconfiguration and reacquisition by the WSC is required and must be initiated by a GCMR from the customer MOC.

NOTE

Failure to observe these conventions may result in WSC rejection of reconfiguration messages, excessive acquisition times, and unnecessary loss of customer platform return service data.

e. DG2 Mode Transitions:

1. DG2 noncoherent to DG2 coherent Transitions. A TDRSS KuSA forward service must be scheduled to be established prior to customer MOC transmission of the GCMR to reconfigure the TDRSS for DG2 coherent operations (refer to paragraph 7.3.5.b.(1)).
2. DG2 coherent to DG2 noncoherent Transitions. When the customer platform switches to the noncoherent mode, the resulting customer transmit frequency offset will probably cause the WSC to drop TDRSS KuSA return service signal lock when the switch is made. If return service signal lock is lost, reconfiguration and reacquisition by the WSC is required and must be initiated by a GCMR from the customer MOC.

NOTE

Failure to observe these conventions may result in WSC rejection of reconfiguration messages, excessive acquisition times, and unnecessary loss of customer platform return service data.

Table 7-9. TDRSS KuSA Return Service Customer Platform Signal Constraints

Parameter (Notes 1 and 2)	**Description** (Notes 1 and 2)
Minimum channel bit transition density (Note 3)	≥128 randomly distributed bit transitions within any sequence of 512 bits
Consecutive channel data bits without a data bit transition (Note 3)	≤64 data bits
Data asymmetry (peak) (Note 3)	≤ ± 3 percent
Data rise time (Note 3) (90 percent of initial state to 90 percent of final state)	≤5 percent of data bit duration but > 800 psec
Symbol (data) bit jitter and jitter rate (Note 3)	≤ 0.1 percent (see Appendix E)
Phase imbalance	
DG1 modes 1 and 2	≤ ± 5 degrees
DG1 mode 3	≤ ± 3 degrees
DG2	≤ ± 3 degrees
Gain imbalance	
DG1 modes 1 and 2	≤ ± 0.50 dB
DG1 mode 3	≤ ± 0.25 dB
DG2	≤ ± 0.25 dB
Phase nonlinearity (applies for all types of phase nonlinearities) (peak)	
DG1 modes 1 and 2	≤ 4 degrees over ±2.1 MHz
DG1 mode 3	≤ 3 degrees over ±80 MHz
DG2	≤ 3 degrees over ±80 MHz
Gain flatness (peak)	
DG1 modes 1 and 2	≤0.4 dB over ±2.1 MHz
DG1 mode 3	≤0.3 dB over ±80 MHz
DG2	≤0.3 dB over ±80 MHz
Gain slope	
DG1 modes 1 and 2	Not Specified
DG1 mode 3	≤0.1 dB/MHz over ±80 MHz
DG2	≤0.1 dB/MHz over ±80 MHz
AM/PM	
DG1 modes 1 and 2	≤15 deg/dB
DG1 mode 3	≤12 deg/dB
DG2	≤12 deg/dB

Table 7-9. TDRSS KuSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1 and 2)	**Description** (Notes 1 and 2)
Noncoherent frequency stability (peak) (Notes 4, 5)	
±5 kHz customer oscillator frequency uncertainty	
1-sec average time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 1 \times 10^{-7}$
48-hr observation time	$\leq 3 \times 10^{-7}$
±20 kHz customer oscillator frequency uncertainty	
1-sec average time	$\leq 3 \times 10^{-9}$
5-hr observation time	$\leq 4 \times 10^{-7}$
48-hr observation time	$\leq 1.2 \times 10^{-6}$
Incidental AM (peak)	
For open-loop pointing	
At frequencies ≥100 Hz	≤5 percent
For autotrack performance	
At frequencies: 10 Hz-10 kHz	≤3 percent
At frequencies: 10 Hz-2 kHz	≤0.6 percent (Note 6)
Spurious PM	≤2 degrees
Minimum 3-dB bandwidth prior to power amplifier	
DG1	≥4.5 MHz or two times maximum baud rate, whichever is larger
DG2	≥2 times maximum channel baud rate
Phase noise (rms) (Note 7)	
DG1 Mode 1	
Doppler Tracking Required	
All Baud rates	
1 Hz – 10 Hz	≤3.0° rms
10 Hz – 1 kHz	≤3.0° rms
1 kHz – 150 MHz	≤1.4° rms

Table 7-9. TDRSS KuSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1 and 2)	**Description** (Notes 1 and 2)
Phase noise (rms) (Note 7) (cont'd)	
DG1 Mode 1 (cont'd)	
Doppler Tracking NOT Required (Note 8)	
Channel baud rate < 16 ksps	
1 Hz – 10 Hz	≤4.0° rms
10 Hz – 1 kHz	≤3.0° rms
1 kHz – 150 MHz	≤1.4° rms
Channel baud rate ≥ 16 ksps	
1 Hz – 10 Hz	≤ 25.0° rms
10 Hz – 1 kHz	≤ 3.0° rms
1 kHz – 150 MHz	≤ 2.0° rms
DG1 Mode 2	
Doppler Tracking Required	
Channel baud rate < 16 ksps	
1 Hz – 10 Hz	≤ 4.0° rms
10 Hz – 100 Hz	≤ 3.0° rms
100 Hz – 1 kHz	≤ 1.8° rms
1 kHz – 150 MHz	≤ 1.4° rms
Channel baud rate ≥ 16 ksps	
1 Hz – 10 Hz	≤ 15.0° rms
10 Hz – 1 kHz	≤ 4.0° rms
100 Hz – 1 kHz	≤ 2.0° rms
1 kHz – 150 MHz	≤ 2.0° rms
Doppler Tracking NOT Required (Note 8)	
Channel baud rate < 16 ksps	
1 Hz – 10 Hz	≤ 4.0° rms
10 Hz – 100 Hz	≤ 3.0 ° rms
100 Hz – 1 kHz	≤ 1.8° rms
1 kHz – 150 MHz	≤ 1.4° rms
Channel baud rate ≥ 16 ksps	
1 Hz – 10 Hz	≤ 25.0° rms
10 Hz – 100 Hz	≤ 4.0° rms
100 Hz – 1 kHz	≤ 2.0° rms
1 kHz – 150 MHz	≤ 2.0° rms

Table 7-9. TDRSS KuSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1 and 2)	**Description** (Notes 1 and 2)
Phase noise (rms) (Note 7) (cont'd)	
DG1 Mode 3	
Doppler Tracking Required	
All baud rates	
1 Hz – 10 Hz	≤3.0° rms
10 Hz – 1 kHz	≤2.6° rms
1 kHz – 150 MHz	≤1.2° rms
Doppler Tracking NOT Required (Note 8)	
Channel baud rate < 16 ksps	
1 Hz – 10 Hz	≤3.5° rms
10 Hz – 1 kHz	≤2.6° rms
1 kHz – 150 MHz	≤1.2° rms
Channel baud rate ≥ 16 ksps	
1 Hz – 10 Hz	≤ 25.0° rms
10 Hz – 1 kHz	≤ 3.0° rms
1 kHz – 150 MHz	≤ 2.0° rms
DG2 Coherent	
Doppler Tracking Required	
All baud rates	
1 Hz – 10 Hz	≤3.0° rms
10 Hz – 1 kHz	≤1.8° rms
1 kHz – 150 MHz	≤1.0° rms
Doppler Tracking NOT Required (Note 8)	
Channel baud rate < 434 ksps	
1 Hz – 10 Hz	≤3.6° rms
10 Hz – 1 kHz	≤1.8° rms
1 kHz – 150 MHz	≤1.0° rms
Channel baud rate between 434 ksps and 6 Msps	
1 Hz – 10 Hz	≤50.0° rms
10 Hz – 1 kHz	≤6.0° rms
1 kHz – 150 MHz	≤2.4° rms
Channel baud rate > 6 Msps	
1 Hz – 10 Hz	≤50.0° rms
10 Hz – 1 kHz	≤5.5° rms
1 kHz – 150 MHz	≤1.1° rms

Table 7-9. TDRSS KuSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1 and 2)	**Description** (Notes 1 and 2)
Phase noise (rms) (Note 7) (cont'd)	
DG2 Noncoherent	
Doppler Tracking Required	
Channel baud rate < 108.5 ksps	
1 Hz – 10 Hz	≤ 4.0° rms
10 Hz – 100 Hz	≤ 2.5° rms
100 Hz – 1 kHz	≤ 1.4° rms
1 kHz – 150 MHz	≤ 1.4° rms
Channel baud rate < 108.5 ksps	
1 Hz – 10 Hz	≤ 15.0° rms
10 Hz – 100 Hz	≤ 5.5° rms
100 Hz – 1 kHz	≤ 2.0° rms
1 kHz – 150 MHz	≤ 2.0° rms
Doppler Tracking NOT Required (Note 8)	
Channel baud rate < 108.5 ksps	
1 Hz – 10 Hz	≤ 4.0° rms
10 Hz – 100 Hz	≤ 2.5° rms
100 Hz – 1 kHz	≤ 1.4° rms
1 kHz – 150 MH	≤ 1.4° rms
Channel baud rate between 108.5 ksps and 6 Msps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 100 Hz	≤ 5.5° rms
100 Hz – 1 kHz	≤ 2.4° rms
1 kHz – 150 MHz	≤ 2.4° rms
Channel baud rate > 6 Msps	
1 Hz – 10 Hz	≤ 50.0° rms
10 Hz – 100 Hz	≤ 10.0° rms
100 Hz – 1 kHz	≤ 2.0° rms
1 kHz – 150 MHz	≤ 2.0° rms
In-band spurious outputs, where in-band is twice the maximum channel baud rate	
DG1 modes 1 and 2	≥ 23 dBc
DG1 mode 3	≥ 30 dBc
DG2	≥ 30 dBc
Out-of-band emissions	See Appendix D for allowable limits on out-of-band emissions, including spurs

Table 7-9. TDRSS KuSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1 and 2)	**Description** (Notes 1 and 2)
I/Q data skew (relative to requirements for I/Q data synchronization where appropriate) (peak) (Note 3)	$\leq$3 percent
I/Q PN chip skew (relative to 0.5 chip)	$\leq$0.01 chip
PN chip rate (peak) DG1 mode 2 (relative to absolute coherence with carrier rate)	$\leq$0.01 chips/sec at PN code chip rate
PN power suppression (noncoherent and coherent)	$\leq$0.3 dB
Axial ratio for autotrack	$\leq$3 dB
Data rate tolerance	$\leq\pm$0.1 percent
I/Q power ratio tolerance	$\leq\pm$0.4 dB
Permissible P_{rec} variation (without reconfiguration GCMR from customer MOC) (Note 9)	$\leq$12 dB
Permissible rate of P_{rec} Variation	$\leq$10 dB/sec
Maximum P_{rec}	-149.2 dBW

Notes:

1. The definitions and descriptions of the customer constraints are provided in Appendix E.
2. When a constraint value is listed for a baud rate range and data is transmitted on both channels, the maximum baud rate of the 2 channels should be used to determine the constraint value applicable.
3. When the data is Rate 1/2 convolutionally encoded, these data bit parameters should be interpreted as symbol parameters. For encoded channels, it is recommended that customers use G2 inversion to increase symbol transition density. Additionally, bi-phase symbol formatting increases symbol transition density.
4. The frequency stability requirements are valid at any constant temperature (±0.5° C) in the range expected during the mission. At a minimum, a temperature range of -10° C to +55° C shall be considered.
5. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of ± 5 kHz. If a customer cannot accurately define their transmit frequency to within ± 5 kHz, a customer can request a reconfiguration which would expand the oscillator frequency search to ± 20 kHz after the start of service.
6. The TDRSS design implementation may not provide the stated TDRSS KuSA return service autotrack performance when Prec = Prec (minimum) and the Incidental AM (peak), at frequencies ≤2 kHz, is close to or at 0.6 percent. For TDRSS KuSA return service autotrack performance, either Prec must be increased above Prec(minimum), or the Incidental AM (peak), at frequencies ≤2 kHz, must be more tightly controlled.

Table 7-9. TDRSS KuSA Return Service Customer Platform Signal Constraints (cont'd)

Notes (cont'd):
7. Derivation of the phase noise requirements involved making assumptions about the distribution of the phase noise power in each frequency region. Since no phase noise PSD will exactly match the phase noise power distribution assumed for this derivation, phase noise PSDs which are close to violating the phase noise limits or phase noise PSDs which do violate the phase noise limits should be evaluated on a case-by-case basis to determine their acceptability. 8. Applicable for customers that have no Doppler tracking requirement or can tolerate a total Doppler tracking error greater than 0.2 rad/sec. 9. The minimum SHO EIRP should reflect the minimum Prec expected over the service period, where the Prec can exceed this minimum by no more than 12 dB. An actual customer Prec value that is 12 dB greater than the minimum may cause false PN lock or nonacquisition.

Section 8. KaSA Telecommunications Services

8.1 General

8.1.1 Available Services

TDRSS KaSA services include forward and return telecommunications services. Tracking services are not provided via KaSA. This Section focuses on the RF interface between the TDRS and the customer platform. This interface is characterized by the technical requirements imposed and the operational capabilities provided by the TDRSS. The operational interfaces are described in further detail in Section 10. Data interfaces between the customer MOC and the SN are described in paragraph 3.6.

NOTE

> The DSMC issues Network Advisory Messages (NAMS) to provide up-to-date information on network conditions and constraints. These messages are accessible via the DSMC active NAMS web site at http://128.183.140.27/nam/wnserch.htm. At the time of publication of this revision, the TDRS F9 and F10 spacecraft are not operational. Prior to the next revision of this document, the GSFC MSP will use the NAMs as a means of letting customers know of any performance constraints associated with these spacecraft as well as any of the other TDRS.

8.1.2 Interface Definition

The RF interface between the TDRS and a customer platform is defined in terms of signal parameters, RF characteristics, and field of view.

a. The RF interface for forward service represents the transmission by a TDRS of an appropriately modulated signal at or greater than a minimum specified signal EIRP in the direction of the desired customer platform. KaSA forward (KaSAF) service is discussed in paragraph 8.2.

b. The RF interface for return service defines a minimum received power (P_{rec}) at the TDRS antenna input for a specified data quality at the WSC receiver output. KaSA return (KaSAR) service is discussed in paragraph 8.3.

NOTE

> The KaSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.

8.1.3 Customer Acquisition Requirements

Acquisition and reacquisition by the customer platform of the TDRS transmitted signal requires prediction by the customer MOC of the customer platform receive frequency over various projected time periods. Similarly, acquisition and reacquisition by the WSC of the customer platform signal requires prediction by the customer MOC of the customer platform transmitter frequency over various projected time periods. The frequency predictions are ultimately incorporated in the Schedule Order (SHO) as customer platform frequencies for the specific service support periods.

8.1.4 TDRSS Acquisition Support to Customers

For each scheduled TDRSS service support period, the customer requirements for signal acquisition/reacquisition, and the TDRSS capabilities to aid acquisition/reacquisition, are as follows:

a. Customer Epoch Uncertainty

   1. Autotrack. The maximum epoch time uncertainty of the applicable customer platform ephemeris supplied to the TDRSS shall be ±2.0 seconds for customer platform operations requiring the TDRSS KaSA return service autotrack process within the TDRSS Primary FOV and Extended Elliptical FOV. Similarly, the maximum epoch time uncertainty of the customer platform ephemeris shall be ±1.5 seconds for the KaSA return service autotrack process within the TDRSS LEOFOV.

      NOTE

      KaSA return autotrack service for the Extended Elliptical FOV will be supported on a best effort basis.

   2. Program track. The maximum epoch time uncertainty of the applicable customer platform ephemeris supplied to the TDRSS shall be ±2.0 seconds for customer platform operations using TDRSS KaSA open-loop pointing within the TDRSS Primary FOV.

   3. LEO Program track. The maximum epoch time uncertainty of the applicable customer platform ephemeris supplied to the TDRSS shall be ±1.5 seconds for customer platform operations requiring the TDRSS KaSA open-loop pointing for customers within the TDRSS LEOFOV.

b. Customer Frequency Uncertainty. The customer MOC must know the operating frequency of the customer platform to within ±6 kHz.

c. Frequency Sweep on the Forward Link. After the start of the forward link service, the TDRSS has a forward service frequency sweep capability of ±30 kHz.

d. Noncoherent Return Expanded Frequency Search. After the start of the return link service, the TDRSS has a return service expanded frequency search capability of ±21 kHz.

8.2 KaSA Forward Services

8.2.1 General

The characteristics of the data provided to the WSC interface and the RF signals provided by the TDRS to the customer platform during TDRSS KaSA forward services are described in paragraphs 8.2.2 through 8.2.5. This discussion assumes that an appropriate forward service has been scheduled and a data signal is present at the WSC interface.

8.2.2 Signal Parameters

The TDRSS KaSA forward service signal parameters are defined in Table 8-1. The center frequency, f_O, of the customer platform receiver must be defined by the customer MOC in its service specification code for TDRSS KaSA forward service (refer to paragraph 10.2.2). A description of the features inherent in the QPSK and BPSK signal parameters listed in Table 8-1 are discussed in paragraphs 8.2.2.1 and 8.2.2.2, respectively.

8.2.2.1 QPSK Signal Parameters

a. Unbalanced QPSK Modulation. The I channel is used to transmit the customer command data and is referred to as the command channel. The Q channel transmits a range signal and is referred to as the range channel. The command channel/range channel power ratio for QPSK forward service signals is +10 dB. This unbalanced QPSK modulation minimizes the power in the range channel to a level adequate for customer platform range channel acquisition and tracking. This feature increases the power in the command channel by 2.6 dB over that for balanced QPSK modulation without increasing customer platform receiver complexity, increasing customer platform command channel acquisition time, or decreasing TDRSS range tracking accuracy.

NOTE

Tracking services are not provided via KaSA.

b. Spread Spectrum. All TDRSS KaSA forward services with data rates $\leq$300 kbps should incorporate spread spectrum modulation techniques to satisfy flux density restrictions imposed upon TDRSS forward services by the NTIA. This modulation scheme includes separate but simultaneous command and range channels. The command channel includes a rapidly acquirable PN code and contains the forward service data. The range channel is acquired separately and contains a PN code which satisfies the range ambiguity resolution requirements. The length of the command channel PN code is 2^{10}-1, where the length of the range channel PN code is 256 times the command channel PN code length. The customer platform command channel acquisition can precede customer platform range channel acquisition; this feature permits

Table 8-1. TDRSS KaSA Forward Service Signal Parameters

Parameter	Description
TDRS transmit carrier frequency (Hz)	F
Carrier frequency arriving at customer platform (note 1)	F_R
Carrier frequency sweep (note 4)	$\pm$30 kHz
Carrier frequency sweep duration (note 4)	120 seconds
QPSK (PN modulation enabled)	
$\frac{\text{Command channel radiated power}}{\text{Range channel radiated power}}$	+10 dB
QPSK Command Channel	
Carrier frequency (Hz)	Transmit carrier frequency (F)
PN code modulation	PSK, $\pm$ π/2 radians
Carrier suppression	30 dB minimum
PN code length (chips)	2^{10} - 1
PN code epoch reference	Refer to 451-PN CODE-SNIP
PN code family	Gold codes
PN code chip rate (chips/sec) (note 5)	$\frac{31}{1469 \times 96} \times (\frac{F}{10^9} - 8.78 - 0.005\,K) \times 10^9$
Data modulation	Modulo-2 added asynchronously to PN code
Data format (note 2)	Not applicable
Data rate restrictions (note 2)	1 kbps - 300 kbps
QPSK Range Channel	
Carrier	Command channel carrier frequency delayed π/2 radians
PN code modulation	PSK, $\pm$ π/2 radians
Carrier suppression	30 dB minimum
PN code chip rate	Synchronized to command channel PN code chip rate
PN code length (chips)	$(2^{10} - 1) \times 256$
PN code epoch reference	All 1's condition synchronized to the command channel PN code epoch.
PN code family	Truncated 18-stage shift register sequences

Table 8-1. TDRSS KaSA Forward Service Signal Parameters (Cont'd)

Parameter	Description
BPSK (PN modulation disabled)	
Carrier frequency (Hz)	Transmit carrier frequency (F)
Data modulation	PSK, $\pm\pi/2$ radians
Carrier suppression	30 dB minimum
Data format (note 2)	Not Applicable
Data rate restrictions (notes 2, 3)	300 kbps - 25 Mbps

Notes:

1. The center frequency, f_o, of the customer platform receiver must be defined by the customer MOC in its service specification code to an integral multiple of 10 Hz. Doppler compensation will be available for $\dot{R} \leq 7.9$ km/sec. During periods of Doppler compensation, $F_R = f_o \pm E$ Hz; where f_o = nominal center frequency of customer platform receiver as defined by the customer MOC and E = (550 x $\ddot{R}$) + C for $\ddot{R} \leq 11.4$ m/sec^2 and C = 10 Hz. If Doppler compensation is inhibited after the start of the forward service, the customer receive frequency will be fixed at the frequency of the Doppler compensation profile at the time of inhibition.

   Forward service Doppler compensation will not increase the effective frequency rate of change seen at the customer receiver more than 28 Hz/sec relative to the frequency for a Doppler free carrier.
2. The forward data rate in this table is the baud rate that will be transmitted by the TDRSS (includes all coding and symbol formatting). For non-WDISC customers, forward data conditioning is transparent to the SN. For all customers, forward convolutional coding is transparent to the SN. These transparent operations should be performed by the customer prior to transmission to the SN data interface. Refer to paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities. Currently, the WSC data interface supports up to 7 Mbps; however, upgrades to support up to 25 Mbps are planned.
3. The SN is capable of supporting BPSK signals at data rates less than 300 kbps; however, its use will be controlled and must be coordinated with the GSFC MSP.
4. After the start of the KaSA forward service, if a customer MOC is unable to accurately define f_o (the nominal center frequency of the customer platform receiver), the forward service carrier frequency can be swept. The KaSA forward service frequency sweep will be initiated by the WSC at f_o-30 kHz and linearly swept to f_o+30 kHz in 120 seconds and held at f_o+30 kHz thereafter. The KaSA forward service frequency sweep does not impact simultaneous WSC Doppler compensation of the KaSA forward service carrier and PN code rate (if applicable).
5. "K" = $\dfrac{\frac{f_o}{10^6} - 22555}{5}$ Rounded to the nearest integer if K $\neq$ integer and $0 \leq K \leq 198$.

   f_o is the nominal center frequency in Hz of customer platform receiver as defined by the customer MOC.

rapid acquisition of the range channel by limiting the range channel PN code search to only 256 chip positions while the range channel PN code itself contains 261,888 chips. The PN code chip rate is coherently related to the TDRS transmit frequency in all cases. This feature permits the customer platform receiver to use the receiver PN code clock to predict the received carrier frequency, thereby minimizing receiver complexity and reducing acquisition time. 451-PN CODE-SNIP defines all the salient characteristics for the forward range and command channel PN code libraries. The agency Spectrum Manager responsible for PN code assignments will allocate a customer platform-unique PN code assignment from these libraries. The GSFC Spectrum Manager is responsible for NASA PN code assignments.

c. Asynchronous Data Modulation. For data rates $\leq$ 300 kbps, the forward service data received at WSC from the NISN data transport system is directly modulo-2 added by WSC to the command channel PN code sequence. The forward service data will be asynchronous with the carrier and the PN code.

NOTE

> When the command channel does not contain any actual forward service data, the forward service command channel signal is the command channel PN code sequence.

d. Functional Configurations. A further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in section B.2.2.

e. Doppler Compensation. The TDRSS KaSA forward service carrier frequency (F) and the PN chip rate transmitted by a TDRS can optionally be compensated by the WSC for Doppler. When compensated, the carrier, F_R, arrives at the customer platform receiving system within a predictable tolerance (E) of f_o as defined in Table 8-1. This feature minimizes the Doppler resolution requirements of the customer platform receiver and is available continuously to facilitate reacquisition by the customer platform in the event of loss of lock of the TDRSS KaSA forward service signal. Customers are encouraged to utilize Doppler compensation at all times. Doppler compensation may be inhibited and the TDRSS will transmit a fixed frequency KaSA forward service carrier and PN code chip rate.

8.2.2.2 BPSK Signal Parameters:

a. BPSK Modulation. For data rates greater than 300 kbps, there is no PN code modulation and the customer data directly BPSK modulates the carrier by $\pm\pi/2$ radians.

NOTE

The SN is capable of supporting non-spread BPSK signals at data rates less than 300 kbps; however, its use will be controlled and must be coordinated with the GSFC MSP.

b. Asynchronous Data Modulation. The forward service data will be asynchronous with the carrier.

NOTE

When the command channel does not contain any actual forward service data, the forward service command channel signal is carrier only.

c. Functional Configurations. A further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in section B.2.2.

d. Doppler Compensation. The TDRSS KaSA forward service carrier frequency (F) transmitted by a TDRS can optionally be compensated by the WSC for Doppler. When compensated, the carrier, F_R, arrives at the customer platform receiving system within a predictable tolerance (E) of f_o as defined in Table 8-1. This feature minimizes the Doppler resolution requirements of the customer platform receiver and is available continuously to facilitate reacquisition by the customer platform in the event of loss of lock of the TDRSS KaSA forward service signal. Customers are encouraged to utilize Doppler compensation at all times. Doppler compensation may be inhibited and the TDRSS will transmit a fixed frequency KaSA forward service carrier.

8.2.3 Communications Services

The TDRSS KaSA forward services available are listed in Table 8-2. Table 8-3 lists their salient characteristics. The definitions for the parameters listed in Table 8-3 are contained in Appendix E.

8.2.4 Real-Time Configuration Changes

Changes to the operating conditions or configuration of a TDRSS KaSA forward service during a scheduled service support period are usually initiated by a Ground Control Message Request (GCMR) from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the GCMR at the WSC. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning WSC response times for the GCMRs is provided in Section 10. Table 8-4 lists the KaSA forward service real-time configuration changes and their effects on the forward service signal.

Table 8-2. TDRSS KaSA Forward Service

Parameter	Description		
Field of view (FOV) (each TDRS) (note 5)	Primary (PFOV) ±22 degrees east-west ±28 degrees north-south (rectangular)	LEO (LEOFOV) ±10.5 degree conical	
Customer Ephemeris Uncertainty (along the customer orbital track)	≤ ± 2.0 sec	≤ ± 1.5 sec	
TDRS antenna polarization (note 1)	RHC or LHC selectable		
	Autotrack (PFOV and LEOFOV) (note 3)	LEO Program Track (LEOFOV)	Program Track (PFOV)
TDRS antenna axial ratio (maximum)	1.5 dB over 3-dB beamwidth	1.6 dB	1.7 dB
TDRS signal EIRP (minimum) (note 4)	+63.0 dBW	+59.5 dBW	+56.2 dBW
Transmit center frequency (nominal) (note 2)	22.555 to 23.545 GHz ±0.7 MHz in 5 MHz steps		
RF bandwidth (3dB, minimum)	50 MHz		
Duty factor	100 percent (normal and high power)		

Notes:

1. Operational considerations may limit choice of TDRS antenna polarization. The KaSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.
2. The customer MOC must include the best estimate of the customer platform receiver center frequency at the time of startup of each scheduled service support period in its service specification code (refer to paragraph 10.2.2). The TDRSS KaSA forward service carrier frequency is then implemented by WSC to the accuracy of the WSC frequency standard except during Doppler compensation. The SNIP and the SFCG recommend that only the following six center frequencies be used for KaSA forward service: 23.205 GHz, 23.265 GHz, 23.325 GHz, 23.385 GHz, 23.445 GHz, 23.505 GHz. The data rate and carrier frequency will be constrained such that the first null of the spectrum falls between 22.55 and 23.55 GHz.
3. EIRP values are for a TDRSS forward service with a TDRSS return autotrack service acquired. Return service autotrack acquisition will be achieved within 10 seconds of KaSA return service P_{rec} consistent with the BER or autotrack acquisition, whichever is larger.
4. The autotrack EIRP will be transmitted towards a customer meeting the required ephemeris uncertainties for the Primary FOV or LEOFOV. The program track EIRP will be transmitted towards a customer meeting the required ephemeris uncertainties for the Primary FOV. The LEO program track EIRP will be transmitted towards a customer meeting the required LEO ephemeris uncertainties for the LEO FOV. Customers may experience better performance through the KaSA program track and LEO program track services than listed in this document. Performance improvements particular to each customer should be discussed with the GSFC MSP.
5. GRGT is not currently planned to support a TDRS F8-F10 spacecraft. Therefore, KaSA services are not available through GRGT.

Table 8-3. Salient Characteristics for TDRSS KaSA Forward Services

Parameter (Note 1)	**Value** (Note 1)	
	QPSK	BPSK
Command channel radiated power / Range channel radiated power	+10 ±0.5 dB	NA
Modulator phase imbalance (peak)	±3 degrees (for each BPSK channel)	
Modulator gain imbalance (peak)	±0.25 dB	
	QPSK	BPSK
Relative phase between command and range channels	90 ±3 degrees	NA
Data asymmetry (peak) (Note 2)	±3 percent	
Data rise time (90 percent of initial state to 90 percent of final state) (Note 2)	≤5 percent of bit duration	
Phase nonlinearity (peak)	±0.15 radian over ±17.5 MHz	
Gain flatness (peak)	±0.8 dB over ±17.5 MHz	
Gain slope (peak)	±0.1 dB/MHz	
AM/PM	≤7 degrees/dB	
	QPSK	BPSK
PN chip jitter (rms) (including effects of Doppler compensation)	≤1 degree	NA
Data bit jitter (peak) (Note 2)	≤1 percent	
Spurious PM (rms)	≤1 degree	
In-band spurious outputs	≥27 dBc	
Incidental AM (peak)	≤2 percent	
Phase noise (rms)		
1 Hz - 10 Hz	≤2.4 degrees	
10 Hz - 32 Hz	≤2.5 degrees	
32 Hz - 1 kHz	≤5.3 degrees	
1 kHz - 25 MHz	≤2.0 degrees	
	QPSK	BPSK
Command/range channel PN chip skew (peak)	≤0.01 chip	NA
PN chip asymmetry (peak)	≤0.01 chip	NA
PN chip rate (peak) (relative to absolute coherence with carrier rate)	≤0.01 chips/sec at PN code chip rate	NA

Notes:

1. The definitions and descriptions of the salient characteristics are provided in Appendix E.
2. These values are the TDRSS contributions for data asymmetry, data transition time, and bit jitter, assuming perfect forward service data is provided to WSC. The actual contributions by the NISN data transport system are negligible compared to those contributed by the TDRSS, since WSC reclocks the data before it is processed by WSC into the forward service signal.

Table 8-4. KaSA Forward Service Real-Time Configuration Changes

Real-Time Configuration Changes	GCMR	OPM	Forward Service Signal Interruption
Customer Receiver Center Frequency	98/04	OPM 03	Yes
Doppler Compensation Inhibit	98/08	OPM 11	No
Doppler Compensation Reinitiation	98/04	OPM 03	No
Forward Service Reacquisition (note 1)	98/03	OPM 02	Yes
Forward Service Sweep Request (refer to Table 8-1)	98/05	OPM 04	Yes
Data Rate	98/04	OPM 03	No
Polarization	98/04	OPM 03	Yes
Initiation or termination of the command channel PN code (note 2)	98/04	OPM 03	No

Notes:

1. Forward service reacquisition is a TDRSS reinitiation of forward link service by applying a 1 MHz frequency offset for 3 seconds to the predicted customer receive frequency specified in the customer's service specification code (refer to paragraph 10.2.2).
2. Initiation of the command channel PN code enables the range channel. Termination of the command channel PN code disables the range channel.

8.2.5 Acquisition Scenarios

The following acquisition scenarios identify only the technical aspects of TDRSS KaSA forward service signal acquisition by the customer platform and do not include operational procedures related to acquisition:

a. KaSAF Program Track and LEO Program Track Scenarios:

   1. The TDRSS KaSA forward service signal does not depend on a customer platform return service.
   2. Prior to the start of the TDRSS KaSA forward service, the TDRSS KaSA antenna will be open-loop pointed in the direction of the customer platform.
   3. At the start of the TDRSS KaSA forward service as defined by the SHO, the TDRS will radiate, in the direction of the customer platform, a signal compatible with the TDRSS KaSA forward service signal parameters listed in Table 8-1. The EIRP directed towards the customer platform is dependent upon the customer providing an ephemeris uncertainty within the values defined in Table 8-2.
   4. The customer platform receiving system will search for and acquire the command channel PN code (if applicable) and carrier. Normally, a customer MOC will not be transmitting forward service data to the NISN data transport system until the forward service signal has been acquired by the customer platform and the acquisition verified by the customer MOC from customer platform return service telemetry. Some customer

platforms may require that there be no data transitions during the signal acquisition process, while others may merely result in longer acquisition times.

5. For QPSK modulation, the customer platform receiving system will search for and acquire the range channel PN code upon acquisition of the command channel PN code and carrier.
6. Upon completion of forward link acquisition and subsequent customer platform transition to signal tracking, the customer platform transmitting system must remain in a noncoherent mode as coherent operation is not supported through KaSA service.
7. The WSC will continue Doppler compensation of the TDRSS KaSA forward service signal unless requested by the customer MOC to inhibit the Doppler compensation.
8. T_{acq} in the customer platform receiver is a function of the customer platform receiver design and signal-to-noise density ratio.
9. Appendix A provides example link calculations for the TDRSS KaSA forward service.

b. KaSAF Acquisition Scenario with Return Autotrack Services:

1. Prior to return autotrack acquisition, the TDRSS forward service EIRP will be the program or LEO program track values, whichever is applicable based upon customer characteristics (see paragraph 8.2.5.a for a description of the program and LEO program track acquisition scenarios). The EIRP directed towards the customer platform prior to return autotrack acquisition is dependent upon the customer providing an ephemeris uncertainty within the values defined in Table 8-2. The TDRS KaSA autotrack signal EIRP listed in Table 8-2 will be provided after return service autotrack acquisition is achieved.

8.3 KaSA Return Services

8.3.1 General

The RF signals provided by the customer platform to the TDRS and the characteristics of data provided at the WSC interface are defined in paragraphs 8.3.2 through 8.3.5. This discussion assumes that an appropriate return service has been scheduled and a data signal is present at the TDRS interface.

8.3.2 Signal Parameters

The TDRSS KaSA return service signal parameters are listed in Table 8-5. The KaSA return supports only noncoherent, non-spread (Data Group 2 (DG2)) service. Within DG2, there are several types of modulation and a description of these general characteristics is provided in paragraph 8.3.2.1. A description of the features inherent in the DG2 noncoherent services is discussed in paragraph 8.3.2.2.

Table 8-5. TDRSS KaSA Return Service Signal Parameters

Parameter (Note 2)	**Description** (Note 2)
DG2 (note 1)	
Transmit carrier frequency (Hz) (note 4)	F_2
Carrier (F_2) reference (Hz)	
DG2 Noncoherent	Customer platform oscillator
Data modulation (note 1)	BPSK, SQPSK, or QPSK (refer to Appendix B and Table 8-6)
Data format	
Without convolutional encoding	NRZ-L, NRZ-M, NRZ-S, Biϕ-L, Biϕ-M, Biϕ-S
With Rate 1/2 convolutional encoding	NRZ-L, NRZ-M, NRZ-S
Data rate restrictions	
Total (notes 1, 2)	1 kbps - 300 Mbps
I channel	1 kbps - 150 Mbps
Q channel	1 kbps - 150 Mbps
DG2 $\frac{\text{I channel power}}{\text{Q channel power}}$ restrictions	
Single data source-alternate I/Q bits	1:1
Single data source-alternate I/Q encoded symbols	1:1
Single data source-single data channel	NA
Dual data sources	1:1 to 4:1

Notes:

1. Customer platform data configurations, including specific data rate restrictions for coding and formatting, are defined in Table 8-6 for TDRSS KaSA return service (refer also to Appendix B). Unless otherwise stated, the data rate restrictions given in this table assume uncoded and NRZ formatted signals.
2. Unless otherwise noted, all data rate values are to be interpreted as data bit rates, and not as data symbol rates.
3. Data rates and modulation schemes are based upon support through the KaSAR 225 MHz WSC receivers. Other data rates and modulation schemes may be possible when the ground terminal is modified to receive 650 MHz bandwidth. A Ka-band IF service capable of supporting the 650 MHz bandwidth is currently under development. Please contact the GSFC MSP for further information.
4. The center frequency, f_o, of the customer platform transmitter must be defined by the customer MOC in its service specification code to an integral multiple of 10 Hz.

8.3.2.1 General Modulation and Noncoherent Description

a. SQPSK Modulation. SQPSK modulation staggers one channel with respect to the other to prevent synchronous transitions. For signal configurations with identical I and Q symbol rates that are NRZ symbol formatted, SQPSK modulation must be used. The symbols of the Q channel are delayed 1/2 symbol relative to the I channel. For signal configurations that use biphase symbol formatting on either channel and the baud rate of the two channels are identical, SQPSK modulation is used and the transitions of one channel occur at the mid-point of adjacent transitions of the other channel.

b. QPSK Modulation. QPSK modulation is available when there is no relation between the I and Q channel transitions. For dual data source configurations, in which SQPSK is not required, QPSK modulation is used.

c. BPSK Modulation. BPSK modulation is available for single data source configurations that use only one channel of the link.

NOTES

For SQPSK modulation, the spectral characteristics of a customer platform saturated power amplifier will, to a great degree, retain the spectral characteristics of the band-limited input signal to that amplifier. This should result in better control of out-of-band emissions, which, in turn, provides more efficient communications and less interference to customer platform using adjacent frequency channels on the TDRS links.

d. Noncoherent Mode. For noncoherent modes, the customer platform transmitted return link carrier frequency is derived from an on-board local oscillator. The customer platform transmit frequency for noncoherent service must be defined by the customer MOC to an accuracy of $\pm$6 kHz in its service specification code when requesting TDRSS KaSA return service. For customers whose frequency uncertainty is greater than $\pm$6 kHz, an expanded frequency search capability is available.

e. Asynchronous Data Modulation. The data modulation is asynchronous to the carrier.

8.3.2.2 DG2 Signal Parameters

KaSA DG2 signal parameters are discussed for noncoherent operation only. Tracking services are not provided via KaSA operations.

a. DG2 Noncoherent. The DG2 carrier is independent of the TDRSS KaSA forward service carrier frequency. The customer platform transmit frequency for DG2 noncoherent service must be defined by the customer MOC to an accuracy of $\pm$6 kHz in its service specification code when requesting TDRSS KaSA return service. For customers whose frequency uncertainty is greater than $\pm$6 kHz, an expanded frequency search capability of $\pm$21 kHz is available after start of the return service.

b. Functional Configurations. Table 8-6 lists the DG2 KaSA return service functional configurations and a further description of the functional configurations, the I-Q channel ambiguity, and data polarity ambiguity is found in section B.3.3.

8.3.3 Communications Services

To obtain TDRSS KaSA return service performance defined in this paragraph, the customer platform transmitted signal must meet the requirements found in Table 8-7 and signal characteristics specified in Table 8-9. The TDRSS KaSA return service performance defined in this paragraph also assumes return service operation in an AWGN environment. Appendix G discusses performance degradations to the TDRSS KaSA return service due to RFI. Example link calculations are provided in Appendix A. TDRSS KaSAR supports only supports non-powered flight customer dynamics ($\dot{R} \leq$ 7.9 km/sec, $\ddot{R} \leq$ 11.4 m/sec^2, and $\dddot{R} \leq$ 0.013 m/sec^3).

8.3.3.1 Acquisition

The KaSAR service supports acquisition for customer platforms operating under non-powered flight dynamics as defined in Table 8-7. The KaSAR service total channel acquisition times (T_{acq}) are given in Table 8-7 and are the sum of the following:

a. Autotrack acquisition time (when the TDRSS KaSA return service autotrack mode is enabled)

b. Carrier acquisition time

c. Symbol/Decoder synchronization time (for coded data) or Symbol synchronization time (for uncoded data).

T_{acq} assumes that the customer platform return service signal is present at the WSC at the start time of the scheduled return service support period and the process is described below.

a. If autotrack is enabled, autotrack acquisition will commence upon the start of the scheduled return service support period.

b. Carrier acquisition will commence upon autotrack acquisition (if applicable) or upon the start of the scheduled return service support period (if autotrack is disabled).

c. Symbol/Decoder and Symbol synchronization times will be measured from the time carrier acquisition is achieved to the time either symbol synchronization is achieved for uncoded channels or decoder synchronization is achieved for rate 1/2 coded channels. Decoder synchronization is achieved when the Viterbi decoder has selected and implemented the correct blocking of the input symbols (into groups of (G1,G2) symbol pairs) for rate 1/2 codes.

Table 8-6. KaSA Return Service Configurations

Return Service Configuration[5]				Source Data Rate Restrictions and Availability[3,4]			
				DG1 Mode 1, 2, 3 and DG2 Coherent		DG2 Noncoherent[1,2]	
				Data format	Data rate	Data format	Data rate
Single Data Source	BPSK	Rate 1/2 coded		-	-	NRZ	1 kbps – 75 Mbps
						NRZ with biphase symbols	1 kbps – 5 Mbps
		Rate 1/3 coded		-	-	-	-
		Uncoded		-	-	NRZ	1 kbps – 150 Mbps
						Biphase	1 kbps – 5 Mbps
	SQPN	Identical I & Q channel data	Rate 1/2 coded	-	-	-	-
			Uncoded	-	-	-	-
	SQPSK	Rate 1/2 coded alternate I/Q encoded symbols		-	-	NRZ	1 kbps – 10 Mbps
	SQPSK[3]	Alternating I/Q data	Individually rate 1/2 coded	-	-	NRZ	>10 – 150 Mbps
			Individually rate 1/3 coded	-	-	-	-
			Uncoded	-	-	NRZ	>10 – 300 Mbps
Dual Data Sources (data rates are for each source separately)	QPSK[1] or SQPSK[1]	Rate 1/2 coded		-	-	NRZ	1 kbps – 75 Mbps
						NRZ with biphase symbols	1 kbps – 5 Mbps
		Rate 1/3 coded		-	-	-	-
		Uncoded		-	-	NRZ	1 kbps – 150 Mbps
						Biphase	1 kbps – 5 Mbps

✓ Configuration supported

\- Configuration not supported

Notes:

1. For DG2 configurations:
   a. For single data source configurations with data on one channel: BPSK modulation is used.
   b. For single data source configurations with data on both channels: SQPSK modulation and an I:Q power ratio of 1:1 is used. For the alternate I/Q bit configuration, the SN requires the I and Q channels be independently differentially formatted (-M,-S).
   c. For dual data source configurations: SQPSK must be used when there are identical baud rates on the I and Q channels (see paragraph 8.3.2.1.a); QPSK is used for all other configurations; for both SQPSK and QPSK, either an I:Q power ratio of 1:1 or 4:1 is supported. For unbalanced QPSK, the I channel must contain the higher data rate and when the data rate on the I channel exceeds 70 percent of the maximum allowable data rate, the Q channel data rate must not exceed 40 percent of the maximum allowable data rate on that Q channel.
2. Noncoherent configurations require a customer transmit frequency uncertainty of ± 6 kHz. If a customer cannot accurately define their transmit frequency to within ± 6 kHz, a customer can request a reconfiguration which would expand the oscillator frequency search to ± 21 kHz after the start of service.
3. Other modulation schemes may be possible when the ground terminal is modified to receive 650 MHz bandwidth. A Ka-band IF service capable of supporting the 650 MHz bandwidth is currently under development. Please contact the GSFC MSP for further information.
4. Unless otherwise noted, all data rates are to be interpreted as data bit rates, and not as data symbol rates. Refer to paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities.
5. Appendix B describes the functional configurations and associated I-Q channel and data polarity ambiguities. Additionally, Figure B-10 depicts the SN supported convolutional coding schemes. For a channel with rate 1/2 coding and data rates greater than 10 Mbps, the customer transmitter must be configured to use an N-parallel encoder, where N is the number of branch rate 1/2 encoders for the channel. N = channel data rate in bps/1x10^7, where N is rounded to the next higher integer if N is not an integer.

Table 8-7. TDRSS KaSA Return Service

Parameter (Note 4)	**Description** (Note 4)		
Field of view (FOV) (each TDRS)	Primary (PFOV) ± 22 degrees east-west ± 28 degrees north-south (rectangular)	LEO (LEOFOV) ±10.5 degree conical	Extended Elliptical (EEFOV) (F8-F10) (note 12) 24.0 degrees inboard east-west 76.8 degrees outboard east-west ±30.5 degrees north-south
Customer Ephemeris Uncertainty (along the customer orbital track)	≤ ± 2.0 sec	≤ ± 1.5 sec	≤ ± 2.0 sec
TDRS antenna polarization (note 1)	RHC or LHC selectable		
TDRS antenna axial ratio (maximum) (note 11)	After Autotrack Acquisition (PFOV, LEOFOV, and EEFOV) (notes 12, 13) 1.8 dB over 3 dB beamwidth	LEO Program Track (LEOFOV) 2.4 dB	Program Track (PFOV) 2.7 dB
Receive frequency (nominal)	25.25 to 27.50 GHz (note 9)		
RF channel bandwidth (3 dB, minimum)	225 MHz or 650 MHz (note 10)		
10^{-5} Bit Error Rate (notes 2, 3, 4)	All P_{rec} values are in dBW; dr=data rate in bps		
Orbital Dynamics (free flight)	$\dot{R} \leq 7.9$ km/sec, $\ddot{R} \leq 11.4$ m/sec^2, jerk $\leq .013$ m/sec^3		

Table 8-7. TDRSS KaSA Return Service (cont'd)

Parameter (Note 4)	**Description** (Note 4)		
10^{-5} Bit Error Rate (notes 2, 3, 4) (cont'd)	All P_{rec} values are in dBW; dr=data rate in bps		
Minimum Required P_{rec} (dBW) for uncoded channels (note 11):	<u>Autotrack (PFOV, LEOFOV, and EEFOV) (notes 12, 13)</u>	<u>LEO Program Track (LEOFOV)</u>	<u>Program Track (PFOV)</u>
DG2			
Data rate ≤ 25 Mbps	$-242.6 + 10\log_{10}(dr)$	$-239.1 + 10\log_{10}(dr)$	$-235.2 + 10\log_{10}(dr)$
Data rate > 25 Mbps	$-241.1 + 10\log_{10}(dr)$	$-237.6 + 10\log_{10}(dr)$	$-233.7 + 10\log_{10}(dr)$
Minimum Required P_{rec} (dBW) for Rate 1/2 convolutional encoded channels (note 11):			
DG2			
Data rate ≤ 10 Mbps	$-248.5 + 10\log_{10}(dr)$	$-245.0 + 10\log_{10}(dr)$	$-241.1 + 10\log_{10}(dr)$
Data rate > 10 Mbps	$-247.6 + 10\log_{10}(dr)$	$-244.1 + 10\log_{10}(dr)$	$-240.2 + 10\log_{10}(dr)$
Acquisition (notes 5, 8):			
Orbital dynamics (free flight)	$\dot{R} \leq 7.9$ km/sec, $\ddot{R} \leq 11.4$ m/sec^2, jerk $\leq .013$ m/sec^3		
Total Channel Acquisition Time (assumes the customer return service signal is present at the WSC at the start time of the return service support period)	Sum of the following: 1. Autotrack acquisition time (when the TDRSS KaSA return service autotrack mode is enabled) 2. Carrier acquisition time 3. Symbol/Decoder synchronization time (coded channel) or Symbol synchronization time (uncoded channel)		

Table 8-7. TDRSS KaSA Return Service (cont'd)

Parameter (Note 4)	**Description** (Note 4)		
Acquisition (notes 5, 8):			
Autotrack Acquisition (if applicable):			
Minimum Required P_{rec} with probability > 99% (notes 11, 13)	PFOV $\geq$-184.1 dBW or consistent with the P_{rec} for BER, whichever is greater	LEOFOV $\geq$-188.0 dBW or consistent with the P_{rec} for BER, whichever is greater	EEFOV (note 12) $\geq$-184.1 dBW or consistent with the P_{rec} for BER, whichever is greater
Acquisition Time:	$\leq$ 10 seconds		
Carrier Acquisition:			
Minimum Required P_{rec} (note 11)	Autotrack (PFOV, LEOFOV, and EEFOV) (notes 12, 13) $\geq$ -185.5 dBW or consistent with the P_{rec} for BER, whichever is greater	LEO Program Track (LEOFOV) $\geq$ -182.0 dBW or consistent with the P_{rec} for BER, whichever is greater	Program Track (PFOV) $\geq$ -178.1 dBW or consistent with the P_{rec} for BER, whichever is greater
Acquisition Time ($P_{acq} \geq$ 90%)			
Noncoherent operations with frequency uncertainty (note 6):			
$\leq \pm$ 6 kHz	$\leq$ 1 sec		
$\leq \pm$ 21 kHz	$\leq$ 3 sec		

Table 8-7. TDRSS KaSA Return Service (cont'd)

Parameter (Note 4)	**Description** (Note 4)
Acquisition (notes 5, 8):	
Channel Decoder/Symbol Synchronization Acquisition (coded data) (note 7):	
Minimum data bit transition density	≥ 64 randomly distributed data bit transitions within any sequence of 512 data bits
Number of consecutive data bits without a transition	≤ 64
P_{rec} (dBW)	consistent with the P_{rec} for BER
Acquisition time (in seconds) with >99% probability:	
Biphase NRZ	< 1100/(Channel Data Rate in bps) < 6500/(Channel Data Rate in bps)
Channel Symbol Synchronization Acquisition (uncoded data) (note 7):	
P_{rec} (dBW)	consistent with the P_{rec} for BER
Synchronization	Achieved when error rate for next 1000 bits is $\le 10^{-5}$
Channel Symbol Synchronization Acquisition (uncoded data) (note 7) (cont'd):	
Acquisition time (in seconds) with >99% probability:	
Biphase NRZ	< 300/(Channel Data Rate in bps) < 3000/(Channel Data Rate in bps)
Signal Tracking	refer to paragraph 8.3.3.3
Orbital dynamics (free flight)	$\dot{R} \le 7.9$ km/sec, $\ddot{R} \le 11.4$ m/sec^2, jerk $\le .013$ m/sec^3

Table 8-7. TDRSS KaSA Return Service (cont'd)

Parameter (Note 4)	**Description** (Note 4)
Reacquisition Orbital dynamics (free flight)	refer to paragraph 8.3.3.4 $\dot{R} \le 7.9\ \mathrm{km/sec}$, $\ddot{R} \le 11.4\ \mathrm{m/sec^2}$, jerk $\le .013\ \mathrm{m/sec^3}$
Duty Factor	100 percent

Notes:

1. Operational considerations may limit choice of TDRS antenna polarization. The KaSA forward and return polarization must be the same in order to obtain simultaneous forward and return services through the same TDRS SA antenna.
2. The BER is for a customer platform transmitting a signal on an AWGN channel which complies with the constraints defined in Table 8-9. Refer to Appendix G for a discussion of the additional degradation applicable to the TDRSS KaSA return service performance due to Ka-band RFI.
3. The required customer P_{rec} must meet the P_{rec} for BER, autotrack acquisition, or signal acquisition, whichever is greatest. Paragraph 8.3.3.2.b provides the required P_{rec} description for each possible KaSAR data configuration. Refer to Appendix A, paragraph A.4, for a definition of P_{rec}. The minimum required P_{rec} equations for BER produce the minimum P_{rec} for a given data rate for all possible signal characteristics. CLASS analysis will produce a more accurate performance projection based upon desired customer signal characteristics, such as data rate, data type, and jitter values. SN support may be possible for customers whose P_{rec} is less than the required P_{rec} for 10^{-5} BER performance as long as the customer is willing to accept support on a best-effort basis and less than 100 percent coverage. Any customer interested in receiving this marginal SN coverage shall be required to negotiate all support with the GSFC MSP.
4. All data rate values (and notes which modify these values, based upon specific signal format and encoding restrictions) are to be interpreted as data bit rates, and not as data symbol rates.
5. For acquisition, the minimum P_{rec} value listed applies to the total (I+Q)P_{rec}. Acquisition requires the P_{rec} to also be consistent with the P_{rec} required for BER, whichever is greater. Failure to provide the minimum P_{rec} for autotrack acquisition at the start of service may preclude successful TDRSS autotrack pullin.

Notes (cont'd):

6. Noncoherent configurations (DG1 mode 2 and DG2 noncoherent) require a customer transmit frequency uncertainty of ± 6 kHz. If a customer cannot accurately define their transmit frequency to within ± 6 kHz, a customer can request a reconfiguration which would expand the oscillator frequency search to ± 21 kHz after the start of service.
7. For symbol synchronization and symbol/decoder synchronization, the minimum symbol transition density and consecutive symbols without a transition must meet the specifications defined in Table 8-9. For encoded channels, it is recommended that customers use G_2 inversion to increase symbol transition density. Additionally, biphase symbol formatting increases symbol transition density.
8. All minimum P_{rec} values include atmospheric and rain attenuation on the link from TDRS to WSC; however, service outages may be experienced during periods of heavy rain.
9. The receive center frequencies supported through KaSAR are: 1) 25.2534 to 27.4784 GHz ±0.7 GHz in 25 MHz steps and 2) the SNIP and the SFCG recommended center frequencies of 25.60 GHz, 25.85 GHz, 26.10 GHz, 26.35 GHz, 26.60 GHz, 26.85 GHz, 27.10 GHz, and 27.35 GHz. The data rate and carrier frequency will be constrained such that the first null of the spectrum falls between 25.25 and 27.50 GHz.
10. The WSC receivers support KaSAR service for the 225 MHz. A Ka-band IF service capable of supporting the 650 MHz bandwidth is currently under development. Please contact the GSFC MSP for further information.
11. The required P_{rec} for autotrack performance is based upon a customer meeting the required ephemeris uncertainties for the Primary FOV, LEOFOV, or the Extended Elliptical FOV. The required P_{rec} for program track performance is based upon a customer meeting the required ephemeris uncertainties for the Primary FOV. The required P_{rec} for LEO program track performance is based upon a customer meeting the required LEO ephemeris uncertainties for the LEOFOV. Customers may experience better performance through the KaSA program track and LEO program track services than listed in this document. Performance improvements particular to each customer should be discussed with the GSFC MSP.
12. KaSA return autotrack service for the Extended Elliptical FOV will be supported on a best effort basis.
13. The KaSA autotrack service can experience longer outages due to RFI as the SA antenna will track the interfering signal rather than the desired signal. Additionally, the KaSA autotrack system can occasionally "wander" during signal fade or no RF conditions, which can cause a delay in acquisition after the signal is restored to its proper level.

d. After symbol/decoder and symbol synchronization is achieved, KaSA return service channel data is available at the WSC interface.

e. To minimize return data loss, it is recommended that the customer platform transmit idle pattern on its data channels until after it has observed (via the UPD data) that the WSC has completed all of its data channel signal acquisition processes.

f. Requirements for bit error probability and symbol slipping take effect at the time decoder synchronization is achieved for convolutional encoded data and at the time symbol synchronization is achieved for uncoded data.

NOTE

Data and symbol transition densities values higher than the minimums required will reduce these acquisition times.

8.3.3.2 Bit Error Rate (BER)

Table 8-7 provides P_{rec} equations that will result in a customer achieving a BER of 10^{-5} for TDRSS compatible signals. The BER P_{rec} equations are applicable for non-powered flight dynamics and the following conditions:

a. Data encoding. Customer platform transmission of Rate 1/2 convolutional encoded or uncoded signals are supported for KaSA return services. Detailed rate 1/2 coding design is described in Appendix B. Reed-Solomon decoding is available to WDISC customers; typical performance is given in Appendix K.

b. Received Power. P_{rec} is in units of dBW. The customer project, in determining its design requirements for minimum customer platform EIRP, must take into account customer platform transmit antenna pointing losses, the space loss between the customer platform and the TDRS, and the polarization loss incurred between the customer platform transmit antenna and the TDRS receive antenna. The maximum TDRS receive antenna axial ratio is given in Table 8-7 (also refer to Appendix A). For DG2 services, the following conditions apply:

   1. Balanced Power Single Data Source-Alternate I/Q Bits. For a customer platform transmitting alternate I and Q data bits from a data source (single data source-alternate I/Q bits), the total $(I+Q)P_{rec}$ must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 8-7, where dr is the single data source data rate prior to separation into the I and Q channels. The Q/I (power) must be equal to 1:1. Refer to Appendix B for further information on this data configuration.

   2. Balanced Power Single Data Source-Alternate I/Q Encoded Symbols. For a customer platform transmitting alternate I and Q encoded symbols from a data source (single data source-alternate

I/Q encoded symbols), the total (I+Q)P_{rec} must be consistent with the minimum P_{rec} for a 10^{-5} BER listed in Table 8-7, where dr is the single data source data rate prior to the rate 1/2 encoder. The Q/I (power) must be equal to 1:1. Refer to Appendix B for further information on this data configuration.

3. Dual Data Sources. For a customer platform transmitting independent data on the I and Q channels (dual data sources), each channel's P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 8-7, where dr is that channel's data rate. Refer to Appendix B for further information on this data configuration.

4. Single Data Source with Single Data Channel. For a customer platform transmitting one channel, the channel's P_{rec} must be consistent with the P_{rec} for a 10^{-5} BER listed in Table 8-7, where dr is the channel data rate. Refer to Appendix B for further information on this data configuration.

c. Customer Degradations. Further reductions in the TDRSS KaSA return service performance identified in Table 8-7 can occur. The TDRSS KaSA return services and tracking services will be provided without degradation for user customer platform transmitted signal characteristics within the constraints specified in Table 8-9. Customer platform parameters exceeding these constraints can also degrade TDRSS KaSA return service performance. Refer to paragraph 3.5 for guidelines if the constraints in this paragraph cannot be met. Definitions of user customer platform constraints are given in Appendix E.

d. Multipath. The WSC will provide lockup and interference protection from multipath signals reflected from the Earth.

8.3.3.3 Signal Tracking

TDRSS provides KaSA return signal tracking (carrier, symbol synchronization, Viterbi decoder synchronization) for non-powered flight dynamics. During a customer KaSA return service support period, loss-of-lock (carrier, symbol synchronization, and Viterbi decoder) indications appear in the periodically updated User Performance Data (UPD) (every 5 seconds). The KaSA return service shall maintain signal tracking for the following conditions:

a. Cycle Slips. The mean time-between-cycle slip in the WSC carrier tracking loop for each TDRSS KaSA return service will be 90 minutes minimum. This value applies at carrier tracking threshold, which is 3 dB less than the minimum P_{rec} for BER listed in Table 8-7, and increases exponentially as a function of linear dB increases in P_{rec}. Cycle slips may result in channel and/or data polarity reversal. WSC can correct for these reversals under the same conditions as WSC can resolve channel and/or data polarity ambiguity as discussed in Appendix B. The time for the WSC to recover from a cycle slip will be consistent with the time required for the WSC receiver to detect and automatically reacquire the signal.

b. Bit Slippage. For each TDRSS KaSA return service operating with a minimum P_{rec} required consistent with the P_{rec} for BER of Table 8-7 and data transition densities greater than 40% for NRZ symbols or any transition density for biphase symbols, the minimum mean time between slips caused by a cycle slip in the WSC symbol clock recovery loop is either 90 minutes or 10^{10} symbol periods, whichever is greater. For a KaSA return service operating with 1 dB more than the minimum P_{rec} required for the BER, and NRZ symbol transition densities between 25% and 40%, the minimum mean time between slips is either 90 minutes or 10^{10} symbol periods, whichever is greater.

c. Loss of Symbol Synchronization. For each TDRSS KaSA return service with data transition densities greater than 40% for NRZ symbols and any transition density for biphase symbols, the WSC symbol synchronization loop will not unlock for a P_{rec} that is 3 dB less than the minimum P_{rec} required for BER in Table 8-7 (refer also to note 3 of Table 8-7). For NRZ symbol transition densities between 25% and 40%, the WSC symbol synchronizer loop will not unlock for a P_{rec} that is 2 dB less than the minimum P_{rec} required for the BER. In both cases, the BER performance will be degraded when the P_{rec} is less than the minimum required for BER.

d. Loss of Autotrack. Loss of autotrack is detected by WSC when either:

   1. The autotrack SA antenna azimuth/elevation angles diverge from the program track SA antenna azimuth/elevation angles. The check on angle divergence protects the autotrack system from false tracking an interfering signal. When loss of autotrack is detected due to angle divergence, WSC will automatically begin the autotrack acquisition process.

   2. There is a drop in received power to a level that is 3 dB less than the minimum P_{rec} for BER. This ensures that the autotrack system does not cause an increase in pointing error due to return signal fades.

      (a) When loss of autotrack is detected due to signal fades during TDRS F1-F7 KaSAR support, WSC will revert to return program track, transmit a forward link signal towards a customer using the program track EIRP values listed in Table 8-2 (if forward service is scheduled), and automatically begin the return autotrack acquisition process.

      (b) For a maximum of 60 seconds after the first loss of autotrack is detected due to signal fades during TDRS F8-F10 KaSAR support, the TDRS SA antenna will continue to move at the calculated customer platform angular rate. If, within that

60 seconds, the KaSA return service P_{rec} has increased back to or above the minimum level required by the TDRSS KaSA return carrier acquisition, the process should transfer almost immediately to its fine-track mode as the TDRS SA antenna boresight should still be pointed fairly close to the actual direction of the customer platform position. However, if after 60 seconds the KaSA return service P_{rec} has not increased back to or above the minimum level required by the TDRSS KaSA return service carrier acquisition, the WSC reverts to open-loop pointing (program track) the TDRS SA antenna in the calculated direction of the customer platform position. When the WSC reverts to program track, the TDRSS will transmit a forward link signal towards a customer using the program track EIRP values listed in Table 8-2 (if forward service is scheduled). The TDRSS KaSA return service autotrack process will not restart until the KaSA return service P_{rec} has increased back to or above the minimum level required by that process.

8.3.3.4 Reacquisition

For return service autotrack reacquisition process, refer to paragraph 8.3.3.3.d. While in the carrier tracking state, a loss of lock condition induced by a cycle slip will be automatically detected and a reacquisition will be automatically initiated. For a customer platform that continues to transmit the minimum P_{rec} for acquisition and maintains an ephemeris uncertainty as defined in Table 8-7, the normal total channel reacquisition time for non-powered flight dynamics will be less than or equal to that for the initial total channel acquisition, with a probability of at least 0.99. If lock is not achieved within 10 seconds of loss of lock, an acquisition failure notification message will be sent to the MOC and WSC will reinitiate the initial service acquisition process. Upon receipt of the loss-of-lock indications in the UPD, the customer MOC may request a TDRSS KaSA return service reacquisition GCMR (refer to Section 10). It is recommended that the customer MOC delay initiation of the GCMR for at least 35 seconds after initial receipt of the loss-of-lock indications in the UPD.

8.3.3.5 Additional Service Restrictions

a. Sun Interference. The TDRSS KaSA return service performance will not be guaranteed when the center of the sun is within 0.5 degrees of the TDRS KaSA receiving antenna boresight. Additionally, the TDRSS KaSA return service performance will not be guaranteed when the center of the sun is within 1 degree of the boresight of the WSC receiving antenna supporting the TDRS.

b. Mutual Interference. It is possible for mutual interference to exist between KaSA customer platforms operating with the same polarization and frequency. The SN can provide tools to assist customers in interference prediction and interference mitigation.

8.3.4 Real-Time Configuration Changes

Changes to the operating conditions or configuration of a TDRSS KaSA return service during a scheduled service support period are initiated by a GCMR from the customer MOC. The requested changes will be implemented within 35 seconds of receipt of the GCMR at the WSC. The MOC will be notified upon initiation of the requested changes via GCM. Additional information concerning WSC response times for GCMRs is provided in Section 10. Table 8-8 lists the KaSA return service real-time configuration changes and their effects on the return service.

8.3.5 Autotrack/Signal Acquisition Scenarios

The following acquisition scenario identifies only the technical aspects of TDRSS KaSA return service autotrack (if enabled) and signal acquisition by the WSC and does not include operational procedures related to acquisition. Acquisition is dependent upon the customer providing an ephemeris with a maximum epoch uncertainty as defined in Table 8-7:

a. TDRS SA Antenna Pointing:

   1. KaSA Autotrack Description. The TDRSS KaSA return service autotrack process (if enabled) will acquire and track a customer platform KaSA return service signal providing a improved pointing of the TDRS SA antenna in the direction of the customer platform. This decreases the required P_{rec} at the input to the TDRS antenna. TDRSS KaSA return autotrack service is independent of whether a TDRS forward service signal is concurrently scheduled.

   2. Autotrack Power Requirement. For the TDRSS KaSA return service autotrack process to acquire a customer platform signal, the KaSA return service P_{rec} must be consistent with either the P_{rec} required for autotrack acquisition or the P_{rec} required for BER, whichever is greater (refer to Table 8-7).

   3. Program track Operational Process. The WSC open-loop points the TDRS SA antenna in the calculated direction of the customer platform. The acquisition process begins with carrier acquisition as described below for coherent or noncoherent operations as applicable.

Table 8-8. KaSA Return Service Real-Time Configuration Changes

Real-Time Configuration Changes	GCMR	OPM	Return Service Interruption
Return Service Reacquisition	98/03	OPM 03	Yes
Noncoherent Expanded Customer Spacecraft Frequency Uncertainty	98/07	OPM 07	No
Channel Data Rate	98/04	OPM 03	No
Noncoherent Transmit Frequency	98/04	OPM 03	Yes
Redefinition of customer minimum EIRP	98/04	OPM 03	Yes
Redefinition of customer maximum EIRP	98/04	OPM 03	No
I/Q Power Ratio	98/04	OPM 03	Yes
Channel Data Format	98/04	OPM 03	No
Channel Data Bit Jitter	98/04	OPM 03	No
Polarization	98/04	OPM 03	No
DG2 Carrier Modulation	98/04	OPM 03	Yes
TDRSS Autotrack Mode	98/04	OPM 03	No
Data Source/Channel Configuration	98/04	OPM 03	Yes
G_2 inversion	98/04	OPM 03	No
Frame Length	98/04	OPM 03	No
Frame Sync Word Length	98/04	OPM 03	No
Frame Sync Word Bit Pattern	98/04	OPM 03	No
Sync Strategy Parameters	98/04	OPM 03	No
Note: Items that are indicated to cause return service interruption will cause the WSC receiver to discontinue signal tracking and attempt to reacquire the return service signal after the appropriate reconfiguration. Any other reconfigurations of the WSC may momentarily affect signal tracking.			

4. Autotrack Operational Process. The WSC initially open-loop points the TDRS SA antenna in the calculated direction of the customer platform. If the TDRSS KaSA return service autotrack process is initiated (or reinitiated), the WSC then processes error signals derived from the received customer platform KaSA return service signal to correct for small error build-ups in moving the TDRS antenna at the calculated angular rate of the customer platform. After the time when the signal is first present at the TDRS with adequate KaSA return service P_{rec} [refer to paragraph (2)], autotrack acquisition will be achieved within the autotrack acquisition time listed in Table 8-7. The acquisition process continues with carrier acquisition as described below for coherent or noncoherent operations as applicable.

5. TDRS Forward EIRP Level. If the TDRSS KaSA return service autotrack process is enabled, the forward service EIRP will default to program track values listed in Table 8-2 during autotrack acquisition. Following the completion of return autotrack acquisition, the forward EIRP will be consistent with the autotrack values listed in Table 8-2. If the return autotrack service experiences a reacquisition, the forward EIRP values may decrease to the program track values. If the TDRSS KaSA return service autotrack process is inhibited, the forward EIRP will be consistent with the program track values listed in Table 8-2, where either LEO program track or program track values depend upon customer platform orbital characteristics.

b. Noncoherent Signal Acquisition Scenario:

1. This mode of customer platform operation does not require a TDRSS forward service signal to be received by the customer platform. However, the customer platform transmitter must be commanded to turn on when noncoherent transmissions are desired, either by stored commands, on-board configuration settings, or direct commands from its customer MOC.

2. The customer platform P_{rec} must be compatible with the minimum P_{rec} required for BER and the other TDRSS KaSA return service signal parameters listed in Table 8-5.

3. At the service start time specified by the SHO, the WSC will begin the search for the customer platform signal based upon predicted Doppler. The WSC corrects the received customer platform signal for Doppler to allow for WSC implementation of receivers with narrow acquisition and tracking bandwidths. The Doppler correction used by WSC is one-way and based on the customer platform transmission frequency stated in the SHO and any subsequent OPMs.

4. WSC will begin carrier acquisition when the P_{rec} meets the minimum required value for this acquisition process. Carrier acquisition may occur prior to completion of autotrack acquisition (if enabled). The WSC will complete acquisition of the customer platform signal (carrier) within the time limits listed in Table 8-7. Return service will be achieved at the WSC receiver output within the total acquisition time limits listed in Table 8-7, which includes WSC symbol and Viterbi decoder synchronization.

Table 8-9. TDRSS KaSA Return Service Customer Platform Signal Constraints

Parameter (Notes 1, 2, and 3)	**Description** (Notes 1, 2, and 3)
Minimum channel bit transition density (Note 4)	≥128 randomly distributed bit transitions within any sequence of 512 bits
Consecutive channel data bits without a data bit transition (Note 4)	≤64 data bits
Data asymmetry (peak) (Note 4)	≤ ± 3 percent
Data rise time (Note 4) (90 percent of initial state to 90 percent of final state)	≤5 percent of data bit duration but > 800 psec
Symbol (data) bit jitter and jitter rate (Note 4)	≤ 0.1 percent (see Appendix E)
Phase imbalance	≤ ± 3 degrees
Gain imbalance	≤ ± 0.25 dB
Phase nonlinearity (applies for all types of phase nonlinearities) (peak)	≤3 degrees over ±80 MHz
Gain flatness (peak)	≤0.3 dB over ±80 MHz
Gain slope	≤0.1 dB/MHz over ±80 MHz
AM/PM	≤12 deg/dB
Noncoherent frequency stability (peak) (Notes 5, 6)	
±6 kHz customer oscillator frequency uncertainty	
1-sec observation time	≤3×10^{-9}
5-hr observation time	≤7.2×10^{-8}
48-hr observation time	≤2.18×10^{-7}
±21 kHz customer oscillator frequency uncertainty	
1-sec observation time	≤3×10^{-9}
5-hr observation time	≤2.54×10^{-7}
48-hr observation time	≤7.64×10^{-7}
Incidental AM (peak)	
For open-loop pointing	
At frequencies ≥100 Hz	≤5 percent
For autotrack performance	
At frequencies: 10 Hz-10 kHz	≤3 percent
At frequencies: 10 Hz-2 kHz	≤0.6 percent (Note 7)
Spurious PM	≤2 degrees

Table 8-9. TDRSS KaSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1, 2, and 3)	**Description** (Notes 1, 2, and 3)
Minimum 3-dB bandwidth prior to power amplifier	≥2 times maximum channel baud rate
Phase noise (rms) (Note 8)	
DG2 Noncoherent	
Doppler Tracking NOT Required (Note 9)	
Channel baud rate < 108.5 ksps	
1 Hz – 10 Hz	≤4.0° rms
10 Hz – 100 Hz	≤2.5° rms
100 Hz – 1 kHz	≤1.4° rms
1 kHz – 150 MHz	≤1.4° rms
Channel baud rate between 108.5 ksps and 6 Msps	
1 Hz – 10 Hz	≤50.0° rms
10 Hz – 100 Hz	≤5.5° rms
100 Hz – 1 kHz	≤2.4° rms
1 kHz – 150 MHz	≤2.4° rms
Channel baud rate > 6 Msps	
1 Hz – 10 Hz	≤50.0° rms
10 Hz – 100 Hz	≤10.0° rms
100 Hz – 1 kHz	≤2.0° rms
1 kHz – 150 MHz	≤2.0° rms
In-band spurious outputs, where in-band is twice the maximum channel baud rate	≥30 dBc
Out-of-band emissions	See Appendix D for allowable limits on out-of-band emissions, including spurs
I/Q data skew (relative to requirements for I/Q data synchronization where appropriate) (peak) (Note 4)	≤3 percent
Axial ratio for autotrack	≤3 dB
Data rate tolerance	≤±0.1 percent
I/Q power ratio tolerance	≤±0.4 dB
Permissible P_{rec} variation (without reconfiguration GCMR from customer MOC) (Note 10)	≤12 dB

Table 8-9. TDRSS KaSA Return Service Customer Platform Signal Constraints (cont'd)

Parameter (Notes 1, 2, and 3)	**Description** (Notes 1, 2, and 3)
Permissible rate of P_{rec} Variation	$\leq$10 dB/sec
Maximum P_{rec}	-143.0 dBW

Notes:

1. The definitions and descriptions of the customer constraints are provided in Appendix E.
2. When a constraint value is listed for a baud rate range and data is transmitted on both channels, the maximum baud rate of the 2 channels should be used to determine the constraint value applicable.
3. These signal constraints apply to the KaSAR 225 MHz through the WSC receivers. Contact the GSFC MSP for signal constraints pertaining to the KaSAR 650 MHz IF service.
4. When the data is Rate 1/2 convolutionally encoded, these data bit parameters should be interpreted as symbol parameters. For encoded channels, it is recommended that customers use G_2 inversion to increase symbol transition density. Additionally, biphase symbol formatting increases symbol transition density.
5. The frequency stability requirements are valid at any constant temperature (±0.5° C) in the range expected during the mission. At a minimum, a temperature range of -10° C to +55° C shall be considered.
6. Noncoherent configurations require a customer transmit frequency uncertainty of ± 6 kHz. If a customer cannot accurately define their transmit frequency to within ± 6 kHz, a customer can request a reconfiguration which would expand the oscillator frequency search to ± 21 kHz after the start of service.
7. The TDRSS design implementation may not provide the stated TDRSS KaSA return service autotrack performance when P_{rec} = P_{rec} (minimum) and the Incidental AM (peak), at frequencies ≤2 kHz, is close to or at 0.6 percent. For TDRSS KaSA return service autotrack performance, either P_{rec} must be increased above P_{rec}(minimum), or the Incidental AM (peak), at frequencies ≤2 kHz, must be more tightly controlled.
8. Derivation of the phase noise requirements involved making assumptions about the distribution of the phase noise power in each frequency region. Since no phase noise PSD will exactly match the phase noise power distribution assumed for this derivation, phase noise PSDs which are close to violating the phase noise limits or phase noise PSDs which do violate the phase noise limits should be evaluated on a case-by-case basis to determine their acceptability.
9. KaSA service does not support Doppler tracking.
10. The minimum SHO EIRP should reflect the minimum P_{rec} expected over the service period, where the P_{rec} can exceed this minimum by no more than 12 dB. An actual customer P_{rec} value that is 12 dB greater than the minimum may cause false PN lock or nonacquisition.

Section 9. Tracking and Clock Calibration Services

9.1 General

The SN can provide customer platform tracking and clock calibration services for MA, SSA (including cross-support), and KuSA telecommunications services. The SN does not provide tracking or clock calibration services for KaSA customers.

NOTE

> For tracking services, the related forward and/or return services must be scheduled for the entire duration of the tracking service and must be described in the same SHO.

The SN provides measurements that help customers:

- Track their platform (range and Doppler)
- Calibrate their platform's clock (time transfer and return channel time delay)

Each of the measurements is briefly described below:

a. Range – The WSC measures range during DG1 mode 1 and 3 operations by counting the time elapsed between the transmission of a PN code epoch on the forward link and the reception of the turned-around PN code epoch on the return link. Only two-way range measurements are provided.

b. Doppler – Doppler is the frequency difference between the return link carrier and a reference frequency, the latter depending on whether two- or one-way Doppler is measured during DG1 or DG2 operations. For <u>two-way</u> Doppler, the reference frequency is the forward link customer platform "receiver frequency" provided to WSC in the SHO; for <u>one-way</u> Doppler, it is the return link customer platform "Transmit Frequency" defined in the SHO. The Doppler count at WSC accumulates "non-destructively"—that is, the counter is not reset during the service.

c. Time transfer – Time transfer measurements are used by MOCs to calibrate their platform's clock. These measurements provide the customer MOC the ability to determine the time difference between the on-board platform clock and the UTC. Only two-way time transfer measurements are provided by the WSC, and only with coherent services.

d. Return channel time delay (RCTD) – RCTD measurements, in conjunction with other data delays, enable the MOCs to calculate the time onboard their platform. RCTD measures the time delay from the WSC antenna input to the WSC baseband output (at the point of time tagging within the data transport) for each I and Q channel in the return link. Unlike time transfer, RCTD can be measured with either a coherent or noncoherent service.

Table 9-1 describes the tracking services available for each return link data group and mode.

NOTE

Cross-support service consists of either MA forward with SSA return, or SSA forward with MA return.

Table 9-1. Tracking Services by Data Group and Mode

Data Group and Mode (note 4)		**Doppler Measurement**		**Range Measurement (note 2)**	**Time Transfer Measurement (note 2)**	**Return Channel Time Delay (note 5)**
		1-Way	**2-Way (note 1)**			
DG1	Mode 1		✓	✓	✓	✓
	Mode 2	✓				✓
	Mode 3 (note 3)		✓	✓	✓	✓
DG2 (note 3)	Coherent		✓			✓
	Noncoherent	✓				✓

Notes:

1. Requires that the customer transponder coherently turns around the received forward service carrier.
2. Requires that the customer transponder coherently turns around the PN code epoch received in the forward service range channel.
3. MAR DG1 mode 3 and DG2 services are only available through TDRSs F8-F10.
4. Tracking services are not available for KaSA service.
5. Return channel time delay is available for symbol rates ≤ 6 Msps for NRZ and ≤ 3 Msps for biphase formats per I or Q channel.

9.2 Range Measurement

a. General. Range measurement is available when the customer platform transmits a PN code on the return link with the epoch synchronized to the received forward link PN code epoch of the range channel transmitted from WSC (i.e., DG1 mode 1 or DG1 mode 3 service configurations). The TDRSS tracking service will be capable of providing accurate and independent (sample-to-sample) range data as indicated in paragraphs b through i with customer platform signal Doppler frequencies and Doppler rates within the ranges listed in Table 9-2.

Table 9-2. Signal Doppler Maxima

Service	Doppler Frequency	Doppler Rate
MA	± 230 kHz	± 1.5 kHz/sec
SSA	± 230 kHz	± 1.5 kHz/sec
KuSA	± 1.6 MHz	± 10.5 kHz/sec

b. Range Measurement Random Error. The random error contribution to range measurement resulting from the TDRSS will not exceed the values listed in Table 9-3 for P_{rec} values consistent with the minimum P_{rec} for BER for the particular service.

Table 9-3. TDRSS Tracking Service Range Measurement Error

Data Rate	Maximum Range Error
< 1000 bps	20 nsec (rms)
≥ 1000 bps	10 nsec (rms)
Note: All data rate values (and notes which modify these values, based upon specific signal format and encoding restrictions) are to be interpreted as data bit rates, and not as data symbol rates.	

c. Range Measurement Systematic Error. The systematic range error contribution from a TDRS will be less than ±35 nsec based on pre-launch measurement and predicted on-orbit performance. The systematic range error contribution from WSC will be less than ±30 nsec.

d. Range Granularity. The range granularity, which is the smallest discrete output of the WSC receiver, is 1 nsec.

e. Range Ambiguity Interval. The minimum unambiguous range measurement is equal to the period (nominally 85 msec) of the TDRSS forward service range channel PN code.

f. TDRSS Delay Compensation. The WSC ranging system will compensate the range measurement for the delays internal to the TDRSS (WSC and TDRS).

g. Data Sampling. Range measurement data is sampled on-time to within ±1 μsec of the WSC epoch times. "On-time" refers to that portion (leading or trailing edge) of the timing signal that is synchronized with UTC at the output of the WSC timing system and is used for sampling the measurement data.

h. Timing Accuracy. The WSC epoch times for range measurement will have a systematic error of less than ±5 μsec of UTC. The WSC epoch times will be traceable to within ±100 nsec of UTC time.

i. Sample Intervals. The sample intervals between range measurement data can be selectable at intervals of 1, 5, 10, 60, and 300 sec/sample.

9.3 Doppler Measurement

a. General. The Doppler frequency is the difference between the recovered carrier frequency and the reference frequency. Two-way Doppler measurement is available when the customer platform transmits a return link carrier frequency that is coherently related to the received forward link carrier frequency (i.e., DG1 mode 1, DG1 mode 3, or DG2 noncoherent service configurations). One-way Doppler measurement is available for signals with a non-coherent return link carrier frequency. The TDRSS tracking service will be capable of providing Doppler information with the accuracy and characteristics specified in paragraphs b through g for customer platform signal Doppler frequencies and Doppler rates within the ranges listed in Table 9-2. The Doppler signal is biased and processed so that a signal of 240. MHz + M f_d is obtained, where M=100 for Ku-band, M=1000 for S-band, and f_d is the Doppler. The Doppler count at the WSC is non-destruct with a WSC capability of maintaining a continuous count for a minimum of 50 minutes. The counter is set to 0 at least 1 second before the start of the tracking service and will not be reset during a service.

NOTE

The definition of 240. MHz is 240.0000 MHz, where the magnitude of the fraction portion is the accuracy of the WSC frequency standard.

b. Doppler Measurement rms Phase Noise. The rms phase noise contribution to Doppler tracking, resulting from the TDRSS, will not exceed the values given in Table 9-4 for P_{rec} values consistent with the minimum P_{rec} for BER for the particular service.

Table 9-4. TDRSS Tracking Service Doppler Measurement rms Phase Noise

ADR (note 1) (bps)	Maximum Phase Noise (note 2) (radians, rms)
≤ 500	0.4
> 500	0.3
≤ 1000	0.3
> 1000	0.2

Notes:
1. All data rate values (and notes which modify these values, based upon specific signal format and encoding restrictions) are to be interpreted as data bit rates, and not as data symbol rates.
2. The error values are in addition to the uncertainty introduced to the Doppler frequency measurement by the allowed ± 25 nsec uncertainty of the 1–second measurement time reference.

c. <u>Reference Frequency</u>.

1. For two-way Doppler measurements, the reference frequency for the WSC Doppler extraction process is coherently related to the forward service transmit frequency consistent with the appropriate frequency turnaround ratio (240/221 for MA and SSA or 1600/1469 for KuSA), assuming no relative motion between the TDRS and the WSC. The TDRS forward transmit frequency defined in the SHO is an integral multiple of 10 Hz. During Doppler compensation inhibit, the TDRS forward service transmit frequency is an integral multiple of 221 for S-band services or 146.9 for Ku-band services. The reference frequency is therefore given by:

$$f_{ref} = f_T\left(\frac{240}{221}\right) \text{ for MA and SSA}$$

$$f_{ref} = f_T\left(\frac{1600}{1469}\right) \text{ for KuSA}$$

where f_T is the TDRS forward service transmit frequency. Two-way Doppler measurements can be provided when Doppler compensation is enabled (DCE) or Doppler compensation is inhibited (DCI). When Doppler compensation is enabled, the forward carrier frequency and PN chip rate are adjusted at WSC so that the customer platform receives its nominal frequency and chip rate. When Doppler compensation is inhibited (accomplished by the WSC only when a Doppler compensation inhibit request is received via an OPM from the DSMC or if Doppler inhibit is scheduled by the SHO), the TDRS forward service transmit frequency is held constant.

2. For one-way Doppler measurements, the reference frequency for the Doppler extractor will be the customer platform transmit frequency as defined in the SHO to the accuracy of the WSC frequency standard.

d. Doppler Granularity. Doppler granularities of 1×10^{-3} cycles for MA and SSA or 1×10^{-2} cycles for KuSA cycle are provided.

e. Data Sampling. Doppler measurement data is sampled on-time to within ±25 nsec of the WSC epoch times. "On-time" refers to that portion (leading or trailing edge) of the timing signal that is synchronized with UTC at the output of the WSC timing system and is used for sampling the measurement data.

f. Timing Accuracy. The WSC epoch times for Doppler measurement will be have a systematic error of less than ±5 µsec of UTC. The WSC epoch times will be traceable to within ±100 nsec of UTC time.

g. Sample Intervals. The sample intervals between Doppler measurement data can be selectable at intervals of 1, 5, 10, 60, and 300 sec/sample.

9.4 Time Transfer Measurement

a. General. Time transfer measurements can be used by MOCs to calibrate their platform's clock. Time transfer measurement is available when the customer platform transmits a PN code on the return link with the epoch synchronized to the received forward link PN code epoch of the range channel (i.e., DG1 mode 1 or DG1 mode 3 service configurations). The TDRSS two-way tracking service will be capable of providing time transfer data as indicated in paragraphs b through g with customer platform signal Doppler frequencies and Doppler rates within the ranges listed in Table 9-2.

Each time transfer measurement consists of two elapsed times…

1. The time elapsed between a reference 1 second time mark and the first forward PN epoch occurring after that reference time.
2. The time elapsed between that same reference time mark and the first return PN epoch received after the first forward PN epoch after that same reference time mark.

…and two corrections that account for the transit times through the SGLT. These corrections are estimates of the following times:

1. Delay from generation of the forward PN epoch until it departs the WSC antenna.
2. Time delay between when a return PN epoch arrives at the WSC antenna and it reaches the point where a time tag is applied.

Time transfer measurements are requested in the SHO. After the scheduled service ends, the DSMC provides the measurements to the customer MOC.

NOTE

> Time transfer measurements can be used by customer MOCs for customer platform clock calibration. The GSFC MSP has developed the "User Spacecraft Clock Calibration System (USCCS) Users' Guide" (http://msp.gsfc.nasa.gov/tdrss/usccs.pdf) and will provide assistance, as necessary. This method can provide improved accuracy over RCTD measurements. USCCS support is not currently available from the GRGT.

b. Time Transfer Measurement rms Error. The jitter in the TDRSS time transfer measurement will be within $\pm$25 nsec.

c. Time Transfer Measurement Systematic Error. Systematic two-way time transfer error contributions will be less than $\pm$35 nsec from a TDRS and less than $\pm$30 nsec from the WSC.

d. Time Transfer Measurement Granularity. The elapsed time between the reference time epoch and the next outgoing forward link PN epoch pulse will have a granularity of 200 nsec. The elapsed time between the reference time epoch and the next arrival of the return link PN epoch pulse will have a granularity of 200 nsec.

e. TDRSS Delay Compensation. The WSC time transfer system provides delay information internal to the TDRSS (WSC and TDRS) that enables the MOC to compensate for those delays in the time transfer measurements.

f. Timing Accuracy. The WSC epoch times for time transfer measurement will be have a systematic error of less than $\pm$5 μsec of UTC. The WSC epoch times will be traceable to within $\pm$100 nsec of UTC time.

g. Sample Interval. The interval between time transfer measurements is 1 second.

9.5 Return Channel Time Delay (RCTD) Measurement

a. General. RCTD measurements are available to any customer platform that transmits a return link signal, coherent or noncoherent. The WSC measures RCTD for each I and Q channel in the return link. The reported value is the time delay from the range-to-zero set reference point in the WSC antenna input to the WSC baseband output reference point, where a UTC time tag is placed on the data stream. RCTD measurements are not currently available from the GRGT.

NOTE

RCTD measurements are available for 4800-bit data block customers. For non-4800-bit data block customers, RCTD measurements are currently not available.

RCTD, in conjunction with other data delays, allows the customer MOC to calculate the time onboard their platform to within about 30 msec, typically.

NOTE

For details on how RCTD measurements can be used by customer MOCs to calculate the time onboard their platform, see "Return Data Delay" at http://msp.gsfc.nasa.gov/tdrss/return_data_delay.htm.

RCTD measurements are requested in the SHO. After the scheduled service ends, the DSMC provides the measurements to the customer MOC.

b. Measurement Times. The WSC measures RCTD at the following times:

1. Immediately before the scheduled service begins.
2. Whenever equipment or services are reconfigured during the service period. Multiple measurements will be made if there are multiple reconfigurations.
3. Immediately after the scheduled service ends.

c. Maximum Symbol Rate. Measurements are provided for symbol rates $\leq$ 6 Msps for NRZ and $\leq$ 3 Msps for biphase formats per I or Q channel.

d. Measurement Accuracy. RCTD measurements have the following accuracies:

Data rates $<$ 250 kbps: $\pm$25% of the data bit period.

Data rates $\geq$ 250 kbps: $\pm$1 μsec. (The maximum symbol rate is defined in Section 9.5. c above.)

e. Measurement Resolution. RCTD measurements are provided in units of microseconds.

Section 10. SN Operations For TDRSS Services

10.1 Purpose And Scope

10.1.1 Purpose

This Section provides a general description of scheduling capabilities, performance monitoring capabilities, and operations interfaces available to SN customers; and discusses how a customer must interface with the SN to obtain TDRSS support.

All SN elements have particular roles to fulfill in support of SN operations (refer to Section 2.3 for an SN element description). The most basic of these responsibilities rest with the customer MOCs, DSMC, WSC, and FDF. Although the MOCs and FDF are not part of the SN, the SN's interactions with the MOCs and FDF are an integral part of SN operations. Table 10-1 presents the basic responsibilities and functions provided by the MOC, DSMC, WSC, and FDF.

NOTE

> The DSMC issues Network Advisory Messages (NAMs) to provide up-to-date information on SN conditions and constraints. These messages are accessable via the DSMC active NAM web site at http://128.183.140.27/nam/wnserch.htm.

10.1.2 Scope

Information covered in this section includes:

a. Scheduling operations (see paragraph 10.2).

b. Real-time operations (see paragraph 10.3).

c. Customer platform emergency operations (see paragraph 10.4).

10.1.3 SN Message Terminology

Different terminology is used to describe the messages exchanged between the DSMC and WSC than is used to describe the equivalent messages exchanged between the DSMC and the MOC. Table 10-2 provides an overview of some of the SN message terminology used throughout this section.

Table 10-1. MOC, DSMC and WSC Responsibilities and Functions

MOC (note 1)	**DSMC** (note 1)	**WSC** (note 1)	**FDF** (note 1)
Focal point for customer platform on orbit operations Provide interface for experiment operations requirements Support experiment scientific data analysis and planning Customer platform evaluation and operations Project operations planning, analysis, and scheduling Health and status maintenance of customer platform and experiments Coordinate computing support Coordinate support requiring multiple customer ground facilities Customer platform command generation Customer platform telemetry processing Customer platform attitude data handling Payload operations and control Experiment sensory analysis and control	Allocate and regulate SN resources Control SN/customer interface Support scheduling SN testing and simulation SN performance monitoring Performance data distribution SN status monitoring Distribution of scheduling and acquisition data Documentation control SN planning Acquisition and tracking control support Data base management Service accountability SN fault isolation	Allocate and control TDRSS services and equipment Provide customer platform telemetry to customer specified destinations (MOC, Data Processing Facility, etc.) via NISN Provide customer platform tracking data to FDF (note 2) Accept customer spacecraft command data from the MOC via NISN Coordinate administrative operations TDRSS performance monitoring Maintain TDRS-to-customer platform communications TDRS health and status operations SN schedule data processing TDRS TT&C operations End-to-End test services	Maintain BRTS system (function as the BRTS MOC) Process BRTS data Generate ground trace predictions Process customer tracking data Generate and transmit real-time state vectors Generate customer orbit and ephemeris data Generate TDRS orbit and ephemeris data from BRTS data Receive and process Tracking Data Messages (TDMs) from WSC

Notes:

1. There is no horizontal correlation among these lists of MOC, DSMC, WSC, and FDF responsibilities and functions. The four lists are independent.
2. In general, raw tracking data is not provided to the customer specified destinations.

Table 10-2. Overview of SN Message Terminology

Purpose	Message Name	From	To
Transmit a schedule message	User Schedule Message (USM)	DSMC	MOC
	Schedule Order (SHO)	DSMC	WSC
Real-time service reconfiguration request	Ground Control Message Request (GCMR)	MOC	DSMC
	Operations Message (OPM)	DSMC	WSC
Real-time service reconfiguration disposition/status	Operations Message (OPM)	WSC	DSMC
	Ground Control Message (GCM)	DSMC	MOC
Real-time performance data	Operations Data Message (ODM)	WSC	DSMC
	User Performance Data (UPD)	DSMC	MOC

10.2 SN Scheduling Operations

10.2.1 General

Scheduling operations are the step-by-step interactions of MOCs and particular SN elements that collectively result in the instructions and information required to direct the SN. This interaction enables the SN to produce the communications and data processing support necessary to conduct real-time customer platform operations.

10.2.2 Database Setup

10.2.2.1 General

The initial step of the scheduling process occurs during the mission planning phase (see paragraph 10.2.3.2). The prospective customer projects supply the DSMC with information needed to fulfill mission support requirements. The customer information is maintained in the NCC Data System (NCCDS) database. The NCCDS is the system resident in the DSMC that schedules SN support. Customer-specific information in the NCCDS database includes:

a. Customer Platform Parameters.

b. Service types.

c. Service Parameter Records.

d. NISN Parameters.

e. Schedule Distribution List.

f. Support Identification (SUPIDEN) and TDRS.

g. Customer Authorization.

h. Data Quality Monitoring (DQM) Setup Parameters.

i. Service Specification Codes (SSCs).

j. Prototype Events.

10.2.2.2 Customer Platform Parameters

For each customer, the customer platform parameters must be specified before any other data can be specified. The customer platform parameters include the customer's Support Identification Code (SIC), Vehicle Identification Code (VIC), Vehicle Identification (VID), and Pseudo-Noise (PN) codes.

10.2.2.3 Service Types

For each customer, the types of service that can be scheduled for that customer must be identified. The service types must be determined before the Service Parameter Records can be specified. Service types include MAF (via F1-F7), SMAF (via F8-F10), SSAF, KuSAF, KaSAF (via F8-F10), MAR (via F1-F7), SMAR (via F8-10), SSAR, KuSAR, KaSAR (via F8-F10), tracking, and end-to-end test services.

10.2.2.4 Service Parameter Records

For each service type for each customer, the Service Parameter Records define how each schedulable parameter is to be validated as the SSCs for that service type and customer are entered into the NCCDS database. The Service Parameter Records comprise similar parameters as the SSC definitions described in Appendix A of the Interface Control Document Between the Network Control Center Data System and the Mission Operations Centers, 451-ICD-NCCDS/MOC. Appendix A shows the range, or set, of values that is generally valid in terms of the DSMC/WSC interface. In contrast, the Service Parameter Records can be customized to specify ranges, or sets, of values unique to each customer.

10.2.2.5 NISN Parameters

For each customer, the NISN parameters specify the settings of certain parameters used in the schedules transmitted to WSC. These parameters are used for purposes such as configuring the MDM system and do not appear in the User Scheduling Messages (USMs).

10.2.2.6 Schedule Distribution List

For each customer, the Schedule Distribution List specifies the destinations to which the NCCDS will transmit fixed USMs. One of these destinations will also be specified as the customer's "primary logical destination" and will receive Schedule Result Messages (SRMs) transmitted in response to schedule requests. Any or all of these destinations may also be specified to receive flexible USMs.

10.2.2.7 SUPIDEN and TDRS

For each customer, the NCCDS database contains a list of valid SUPIDENs. For each valid SUPIDEN, the NCCDS database contains a list of valid TDRSs.

10.2.2.8 Customer Authorization

For each customer, the NCCDS database contains a list of valid customer IDs and associated passwords.

10.2.2.9 DQM Setup Parameters

For a combination of SIC, return service Data Stream ID and data rate, the NCCDS database may contain a set of DQM Setup Parameters. The NCCDS uses the DQM Setup Parameters in the construction of SHOs transmitted to WSC. They do not appear in USMs.

10.2.2.10 Service Specification Codes

The format of the customer data that is contained in a SSC is described in Appendix A of the Interface Control Document Between the Network Control Center Data System and the Mission Operations Centers, 451-ICD-NCCDS/MOC. For each service type to be scheduled, each customer must have at least one SSC specified in the NCCDS database. For each customer, each SSC specifies a set of initial parameter values for the applicable service type. When SSCs ae entered into the database, they are validated according to the Service Parameters Records.

10.2.2.11 Prototype Events

After the SSCs have been established for a customer, it is then possible to define prototype events for that customer. Each prototype event specifies a set of SSCs with associated service durations, service start time offsets, and service-level flexibility parameters. Prototype events are optional. It is possible to schedule SN events without the use of prototype events. However, prototype events can simplify scheduling for customers that repeatedly schedule events with the same structure (i.e., the same set of services with the same durations, relative start times, and flexibility options).

10.2.3 DSMC Scheduling

10.2.3.1 General

The DSMC is responsible for operations management and scheduling SN resources. Scheduling activities consist of the mission planning phase, event scheduling, forecast scheduling, active schedules, scheduling conflicts, and support scheduling.

10.2.3.2 Mission Planning Phase

During the mission planning phase, SN and MOC personnel acquaint each other with the kind of data the MOC must transfer between the SN and the customer platform and with the services the DSMC can make available to the MOC. During this period, the TDRSS service configurations needed to meet the various customer data transfer requirements are defined. Each of these configurations is identified by an SSC used in scheduling SN service.

10.2.3.3 Event Scheduling

a. All customer platform operations supported by the SN are scheduled through the DSMC. The DSMC-generated events schedule is constructed from specific schedule requests submitted by the MOCs. These requests may be either event additions, deletions or replacements. Refer to Table 10-3 for a description of the schedule request types.

b. If the request is for a schedule addition, its addition to the schedule is contingent upon the availability of the SN equipment required to support it. A MOC is responsible for ensuring its own customer platform-to-TDRS visibility prior to adding a schedule event. The MOC may do this directly by submitting schedule requests with start time tolerances that comply with customer platform-to-TDRS visibility requirements, or indirectly by submitting TDRSS Scheduling Windows (TSWs) to the DSMC and then submitting schedule requests that specify that they are to fit within these TSWs. Use of TSWs makes it feasible to submit schedule requests that specify TDRS flexibility and with start time tolerances that exceed a single TDRS view. Refer to paragraph 10.2.4.3 for more information on TSWs.

c. There are several ways MOCs can increase the “schedulability” of their submitted requests. SARs submitted to the DSMC by SN customers may specify time and/or resource flexibility (refer to Table 10-4). Use of scheduling flexibility increases the probability of successfully scheduling a request, and allows for more efficient use of SN resources.

Table 10-3. Schedule Request Descriptions

Schedule Request Type	Description
Schedule Add Request (SAR) (message type 99, message class 10)	Specifies an event to be added to the schedule in terms of: 1. Specific event start and stop times 2. Either a prototype event ID or one or more SSC IDs together with service-level time-related information
Alternate SAR (message type 99, message class 21)	References either a SAR or another Alternate SAR to form a chain of requests. Specifies an event to be added to the schedule.
Schedule Delete Request (message type 99, message class 11)	Identifies an event to be deleted and does not include information such as SSCs
Schedule Replace Request (message type 99, message class 12)	Identifies an event to be deleted, and includes all of the information needed to add a new event

d. Event scheduling in the DSMC complies with the SN scheduling ground rules as specified in paragraphs 2.2.2 and 2.2.3 of the Interface Control Document (ICD) Between the Network Control Center (NCC)/Flight Dynamics Facility (FDF) and the White Sands Complex (WSC), 530-ICD-NCC-FDF/WSC. Compliance with these ground rules ensures that the schedules generated by the DSMC can be supported by the TDRSS. In particular, these ground rules ensure adequate time to configure a resource prior to its use. The actual time required to configure a service within an event varies depending on the resources allocated to the service. In general, the time scheduled by the DSMC to configure a service is the longest time needed to configure any one of the resources allocated to the service. Additional rules also apply to event scheduling. Table 10-5 summarizes the SN scheduling ground rules with an emphasis on the ground rules that apply to time relationships. In general, individual schedule requests submitted by customers must comply with rules that apply to individual events or services while rules that apply to the relationships between events are beyond the control of individual customers.

e. Event scheduling in the DSMC is performed when processing modifications (add, replace and delete requests) to the active schedule and when generating the next forecast schedule. The DSMC Scheduling Operator (SO) is responsible for monitoring and coordinating all scheduling activities within the active period. The DSMC Forecast Analyst (FA), who is chiefly responsible for coordinating future scheduling requirements (forecast periods), assists the DSMC SO in monitoring schedule-related database information, analyzing schedule resource problems, and coordinating alternative support solutions with MOCs.

Table 10-4. Scheduling Flexibility Options

Scheduling Flexibility

1. The DSMC scheduling engine will apply scheduling flexibility in the following order when attempting to schedule a SAR:
   - Resource flexibility (if any) as specified by the SAR. This may include TDRS flexibility, SA antenna flexibility, and User Interface Channel flexibility. (note 1)
   - Start time flexibility (if any) as specified by the SAR. This may include event start time flexibility and/or service start time flexibility. (note 2)
   - Service duration flexibility (if any) as specified by the SAR. (note 3)
2. If a SAR cannot be scheduled after application of all of above flexibility, the DSMC scheduling engine will attempt to schedule an Alternate SAR if the customer has submitted one that references the original SAR.
   - An Alternate SAR has nearly the same format as a SAR, and can specify flexibility in the same way.
   - Alternate SARs can reference SARs or other Alternate SARs. This feature can be used to form a chain of requests which will be processed in sequence until one of the requests is successfully scheduled or until all have been declined.
3. If a SAR and all linked Alternate SARs (if any) are declined and the SAR specified Wait List type processing, the SAR and all of its alternates will be placed on the Wait List. The customer may also submit a Wait List Request after receiving notice that the SAR was declined. (note 4)

Notes:

1. Flexibility always applies to the DSMC's selection of MAR and SMAR links. The customer does not have the option of specifying a particular MAR or SMAR link.
2. Allows specification of plus and minus tolerances on event and/or service start time.
3. Allows reduction of service duration within specified limits; however, duration will never be less than the minimum requested.
4. The Wait List is processed every time the Active Schedule is modified.

Table 10-5. SN Scheduling Event Time Ground Rules

Applicable Event, Service or Resource	**Ground Rules** (note 8)
Event	• Duration cannot be less than one minute • Duration cannot be more than 24 hours • All services in an event are scheduled on the same TDRS and the TDRS must be used continuously from the beginning of the event to the end of the event. There can be no time period within the event in which a service is not scheduled.
Single Access (SA) services and event	• Except for SSAR combining services, all SA services in an event are scheduled on the same SA antenna • SSAR combining services actually use both SA antennas, but message formats will show that SA1 is used. All other SA services in an event containing a SSAR combining services must use SA1.
SA Antenna	• A minimum of 90 seconds is required between consecutive uses of the SA antenna (F1 – F7) in different events • A minimum of 120 seconds is required between consecutive uses of the SA antenna (F8 – F10) in different events (note 1, note 2) • A minimum of 30 seconds is required between consecutive uses of the SA antenna within the same event
MAF or SMAF service	• A minimum of 30 seconds is required between MAF services on the same TDRS (F1 – F7) but in different events • A minimum of 30 seconds is required between SMAF services on the same TDRS (F8 – F10) but in different events
MAR or SMAR Link	• A minimum of 30 seconds is required between uses of the same MAR link on same the TDRS (F1 – F7) but in different events • A minimum of 30 seconds is required between uses of same SMAR link on same the TDRS (F8 – F10) but in different events
EET equipment	• A minimum of 3 minutes and 30 seconds is required between uses of S-band EET for the same TDRS • A minimum of 3 minutes and 30 seconds is required between uses of Ku-band EET for same TDRS
User Interface Channels	• A minimum of 20 seconds is required between uses of same user interface channel (note 4, note 5)
Any service	• A minimum of 15 seconds is required between services of the same type within an event

Table 10-5. SN Scheduling Event Time Ground Rules (Cont'd)

Applicable Event, Service or Resource	Ground Rules (note 8)
Ku band and Ka band services	• A minimum of 20 seconds is required between Ku and Ka band services in same event (note 3)
Customer SA and MA/SMA resources	• The gap between two consecutive events for the same customer must be no less than the gap specified by that customer in the DSMC database. (note 6)
Coherent pair of forward and return services (note 7)	• Any return service configured in coherent mode must be associated with a forward service • The forward and return services should start at the same time for optimal performance • If operational considerations require starting the forward service before the return service, no reconfigurations of the forward service (i.e., OPMs 02, 03, and 11) shall be sent within 30 seconds of the start of return service • Forward link sweep requests (OPM 04) shall not be sent within 150 seconds of the start of the return service
One-way tracking service	• Must be associated with an S-band or Ku-band return service for its full duration
Two-way tracking service	• Must be associated with a pair of S-band forward and return services or a pair of Ku-band forward and return services for its full duration

Notes:

1. As of the commencement of F8 operations, 120 seconds will also be applied to F1-F7.
2. Longer times are needed for extended field of view support. This is handled through operations procedures.
3. Not implemented in DSMC scheduling.
4. A user interface channel is a connection between WSC and the customer facility. In most cases, these connections are via NISN circuits.
5. For many customers, this constraint precludes overlapping events even if the events are scheduled on different TDRSs. However, customers with a sufficiently large set of user interface channels may be able to schedule overlapping events for the same customer platform.
6. Customer-specified gaps are used to prevent scheduling flexibility from positioning two consecutive events for the same customer too close together to be supported by the MOC. Use of customer-specified gaps is optional.
7. These messages will not be rejected, but could cause inaccuracies in subsequently scheduled tracking data.
8. Services are defined as MAF (via F1-F7), SMAF (via F8-F10), SSAF, KuSAF, KaSAF (via F8-F10), MAR (via F1-F7), SMAR (via F8-10), SSAR, KuSAR, KaSAR (via F8-F10), tracking, and end-to-end test.

10.2.3.4 Forecast Scheduling

Generation of the forecast schedule is a weekly occurrence in the DSMC. The forecast schedule, which contains events resulting from FA actions and specific MOC requests, consists of 7 days (0000Z Monday through 2359Z Sunday) of SN support commitments. As illustrated in Figure 10-1, MOCs can start requesting support up to 21 days prior to the start of the event.

a. On Monday of each week, the DSMC FA accepts customer SARs for the forecast week beginning 14 days from the current Monday.

b. The forecast schedule is generated by and totally under the control of DSMC Scheduling. All requests for support for the forecast that are received by 1200Z Monday will be scheduled by priority. Any requests received after this time will be scheduled around the currently scheduled events. The DSMC SO or FA will verbally coordinate the action necessary to resolve any conflicts within the schedule (see paragraph 10.2.3.6). The SO or FA continues the conflict resolution process until a conflict-free forecast schedule is produced satisfying as many requests as possible.

c. The forecast scheduling process culminates in the forecast schedule being issued to MOCs on Monday, 7 days prior to the beginning of the week covered by that forecast schedule. The transmission of this confirmed schedule to the customer MOCs automatically transfers the responsibilities for that time period to the DSMC SO, and this now becomes the active schedule.

10.2.3.5 Active Schedules

a. The active schedule begins at the current time and covers the next 7 to 14 days into the future. Figure 10-1 shows how activation of the forecast schedule extends the active period by 7 days. On the first day of each week (immediately following activation of the forecast schedule), the active schedule is 14 days in length. The length of the active schedule continually decreases until (by the end of the week (Sunday)) the active schedule is 7 days in length. This cycle is then repeated each week with the activation of subsequent forecast schedules.

b. The DSMC transmits an active schedule to the WSC, NISN, and other SN facilities on a daily basis. These schedules are used by appropriate SN elements to reserve the equipment required to meet daily support commitments. The WSC schedule contains the support requirements for the operational TDRSs as well as associated requirements for the WSC SGLTs and data distribution/processing services. The NISN schedule, which consists of all NISN data transport requirements into and out of the WSC in support of SN activities, is used by NISN to monitor utilization of those NISN resources which have been committed to the SN. For additional detail of how this works,

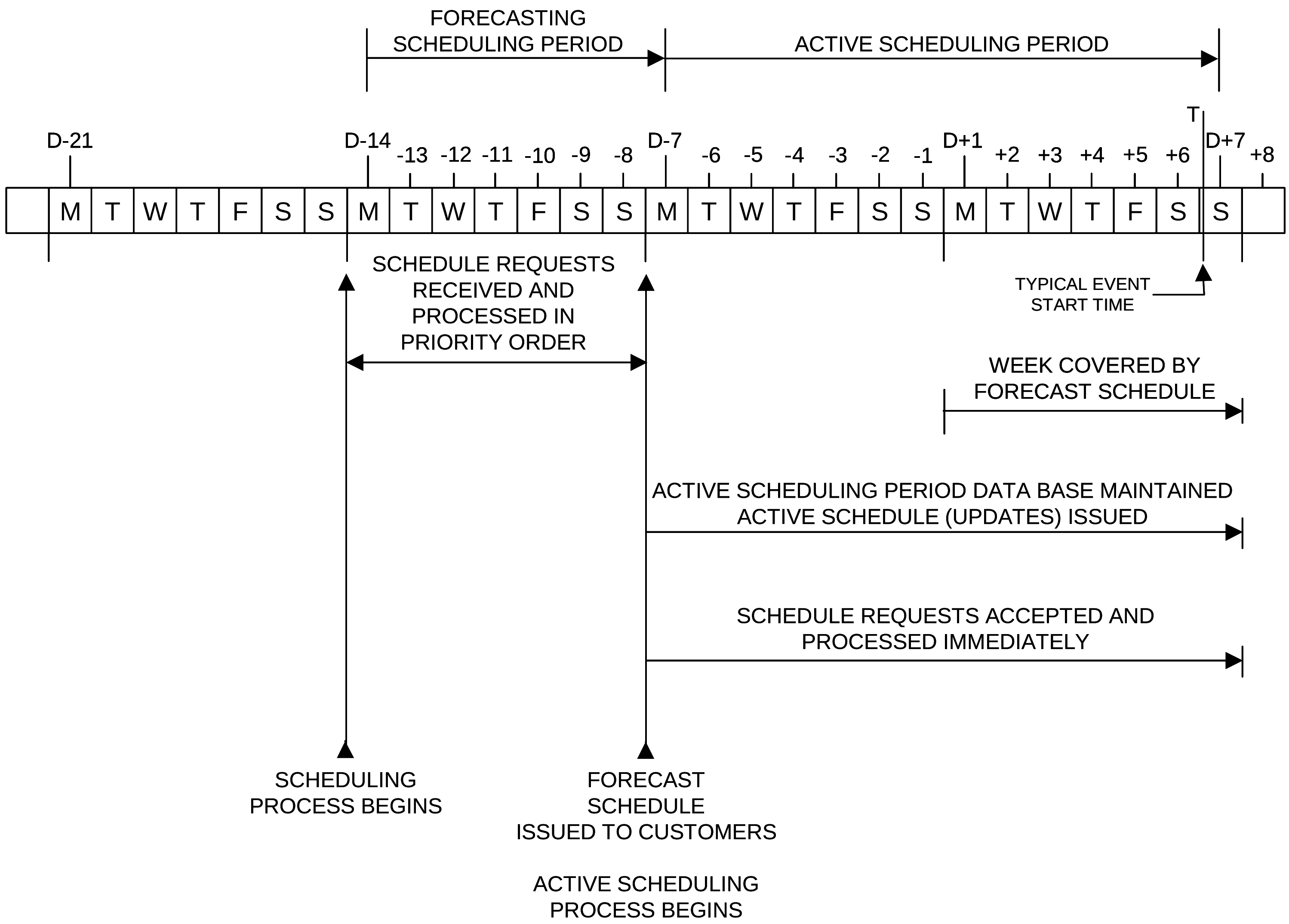


Figure 10-1. SN Event Schedule Process

please refer to the Interface Control Document Between the Network Control Center Data System and the NASA Integrated Services (NISN)/NASA Communications (Nascom) Event Scheduling Terminal (NEST), (451-ICD-NCCDS/NEST). Additionally, the DSMC will transmit recorder/playback requirements to the WSC.

c. The active schedule is constantly being changed as a result of additions or deletions of specific schedule events, operator actions as a result of SN equipment status changes, and other actions. In addition, scheduled support may be affected by customer platform emergencies and/or priority requests by MOCs for additional service. Any changes to the active schedule results in the transmission of active schedule updates to the affected facilities, if schedule information for that time frame had already been transmitted to them. Additionally, the Wait List is processed.

10.2.3.6 Scheduling Conflicts

a. Occasionally a direct conflict occurs between two requested events during the forecast scheduling process. In case of scheduling conflicts that cannot be automatically resolved by use of the resource and time flexibility specified in the schedule requests, the DSMC SO may assist in the analysis of conflicts. Conflict analysis includes the use of priorities provided by NASA, and negotiations between the DSMC SO or FA and impacted MOCs on an individual basis. Conflict analysis is not performed for specific schedule requests applicable to the active schedule unless DSMC SO assistance is verbally requested by the MOC.

b. The DSMC has two systems available to customers in predicting possible radio frequency interference (RFI). The Automated Conflict Resolution System (ACRS) predicts mutual interference (MI) between two or more customer platforms scheduled on the same TDRS at the same time. MOCs receive ACRS output and may alter their schedules based upon the interference mitigation techniques provided by ACRS. The TDRS Look Angle System (TLAS) plots the TDRS look angles as it tracks the customer platform and predicts periods of ground based RFI and earth multipath. Both systems use TDRS and customer orbital data as well as customer schedules received directly at the DSMC. ACRS predicts forward and return link mutual interference. For additional information, refer to the CLASS ACRS/TLAS Operator's Manual and Reference, NCC 98, DRAFT.

10.2.3.7 Support Scheduling

Whenever feasible, SN customers should use the forecast scheduling process to schedule SN events. However, a MOC may submit routine specific schedule requests to the DSMC up to 10 minutes prior to the event start time. A Periodic SHO is transmitted from the DSMC to the WSC for event start times that are greater than 2 hours and less than 48 hours from the time of SHO receipt at WSC. The DSMC transmits a Routine SHO to the WSC for event start times between 10 minutes and 2 hours from the time of SHO receipt at WSC (see section 10.4 for a discussion on customer platform emergency operations).

10.2.4 MOC/DSMC Interfaces

10.2.4.1 General

a. The MOC/DSMC scheduling interfaces normally takes place via the User Planning System (UPS) or an equivalent customer unique system. The UPS, or the equivalent customer unique system, serves as a communications focal point and MOC mission planning tool. However, the DSMC SO can enter schedule requests for any customer at any time. A customer with only limited SN support requirements will not necessarily need an UPS, or equivalent system, and may depend on the DSMC SO for entry of all schedule requests.

NOTE

> The SN is in the process of developing a SN Web Services Interface (SWSI) which will provide a standards-based, cross-platform compatible customer interface for performing TDRS scheduling and real-time service monitoring and control. The intent of the SWSI is not to replace existing scheduling and real-time systems for all SN customers. It is rather to provide a simple low-cost interface option for suborbital and infrequent SN customers.
>
> Using the SWSI, SN customers will be able to perform scheduling, real-time functions, and state vector storage for only the cost of a desktop computer or workstation, a web browser, and a Java Virtual Machine (JVM). The SWSI is designed to be accessed from the NISN Closed IONET or Open IONET. NISN's Open IONET allows access from the NASA Science Internet and the public Internet, thus allowing cooperation with NASA's university, enterprise, and inter/intra-agency partners. For the latest information on SWSI, please contact the GSFC MSP.

b. Scheduling messages may be exchanged between the DSMC and any MOC at any time. Figure 10-2 lists the messages exchanged via this interface. Descriptions of these messages are continued in paragraphs 10.2.4.2 through 10.2.4.6. Additional MOC/DSMC message traffic occurs during SN real-time operations (refer to Section 10.3). All messages exchanged between the

.

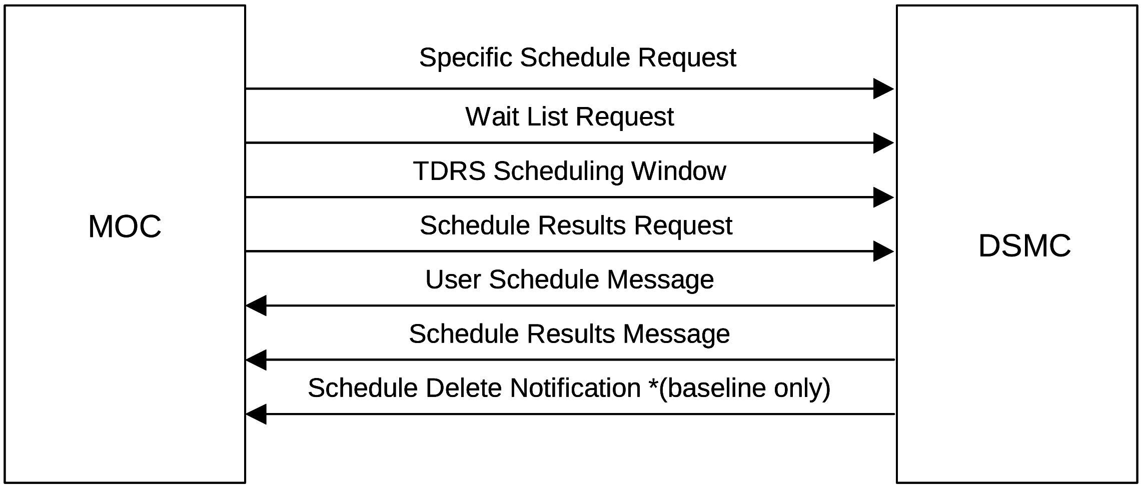


Figure 10-2. MOC UPS/DSMC Scheduling Message Exchange

NCCDS and the MOCs must comply with the formats, protocols, and security provisions specified by the Interface Control Document Between the Network Control Center Data System and the Mission Operations Centers, 451-ICD-NCCDS/MOC.

c. The NCCDS supports two classes of customers. They are referred to as "baseline customers" and "full support customers". Refer to Table 10-6 for more information on the difference in available message types for each class of customer.

10.2.4.2 Specific Schedule Request

The Specific Schedule Request message is used to add, delete or replace scheduled events for SN resources. The following DSMC constraints apply:

a. All related services (e.g., forward, return, tracking and end-to-end test) for one SUPIDEN, for one TDRS, and for one continuous period are generally contained in the same request. However, two independent events for the same SUPIDEN can be scheduled at the same time whenever this does not result in resource conflicts.

b. Deletion of a scheduled event may be accomplished only by the MOC that has scheduling authority, the DSMC SO, or the WSC (with DSMC approval or direction). If the WSC deletes an event, this will not result in automatic generation of messages announcing the deletion.

Table 10-6. NCCDS Customer Types and Available Message Types

NCCDS Customer Types	
Baseline	**Full Support**
Support provided using all message formats in place prior to NCCDS 1998.	Customers capable of using the full set of NCCDS 1998 message formats and any (or all) of the new schedule features such as service duration flexibility.
Specifically:	Specifically:
1. Schedule Deletion Notification message used to notify customers of event deletions.	1. Schedule Delete Notification used to notify customer of event deletions.
2. Schedule Result Message will identify events through the combination of SUPIDEN, TDRS, and Event Start Time parameters (not the Event ID).	2. Schedule Result Message will identify events through use of an Event ID
3. Schedule Delete Request message from the customer will identify events through the combination of the SUPIDEN, TDRS, and Event Start Time parameters (not the Event ID).	3. Schedule Delete Request message will identify an event using an Event ID.
4. Schedule Add Request (SAR) message format does not include parameters applicable to service-level flexibility.	4. Schedule Add Request (SAR) message format includes parameters applicable to service-level flexibility.
	New message types available with NCCDS 1998: Schedule Coordination Messages 1. Schedule Replace Request (99/12) 2. Alternate Schedule Add Request (99/21) 3. Wait List Request (99/24) 4. TDRS Scheduling Window (99/25) 5. Schedule Result Request (99/28) * User Schedule Messages 1. Normal Support, Flexible Schedule (94/04) 2. Simulation Support, Flexible Schedule (94/05)
* A Schedule Result Request message is required by all customers whether they are baseline or full support. All MOCs using the TCP/IP protocol must send a Schedule Result Request message even if they are not full support customers. For MOCs which still use the NISN 4800-bit block protocol, the NPG will generate a Schedule Result Request message for them.	

c. Configuration changes to scheduled events, prior to the scheduled event start time, require the entire event to be replaced by submitting a Schedule Replace Request (message type 99, message class 12). Alternatively, the event can be deleted by submitting a Schedule Delete Request (message type 99, message class 11) and then a new Schedule Add Request (message type 99, message class 10) can be transmitted. Ordinarily these two methods will achieve equivalent results; however, use of the Schedule Replace Request ensures that the resources allocated to the original event are available to be used to schedule the replacement. Use of the Schedule Replace Request also leaves the original event on the schedule if the replacement cannot be scheduled.

d. For add requests, the configuration of services for the event may be specified either by reference to a set of SSCs or by reference to a prototype event which then references a predetermined set of SSCs stored in the NCCDS database.

e. Each SSC represents a single service over one continuous period and designates a predefined set of initial parameter values. In addition, maximum data rate values are specified. SN data rate bandwidth allocation is based on these maximum values rather than on the initial values. The NCCDS will not allow data rate reconfigurations to exceed the specified maximum data rates.

f. Some SSC parameter values (e.g., initial data rate) may be replaced by values specified in the MOC specific schedule request. These are called respecifiable parameters.

g. For a specific request using SSCs, the MOC is required to order the SSCs in the same order the services will be output in the USM (i.e., forward, return, tracking). (Refer to Interface Control Document Between the Network Control Center Data System and the Mission Operations Centers, 451-ICD-NCCDS/MOC).

h. The continuous period covered by an event may range from a minimum of 1 minute to a maximum of 24 hours.

10.2.4.3 TDRS Scheduling Windows

a. TDRS Scheduling Windows (TSWs) are transmitted to the DSMC by the MOC in TSW messages (message type 99, message class 25). Each TSW message contains TSWs applicable to a specified time period for a single customer-defined TSW set for a single TDRS. The TSWs may be transmitted before, after, or at the same time as the schedule requests that depend on the TSWs. However if a schedule request requires TSWs from a particular TSW set for a particular TDRS during a certain time period, it cannot be processed if applicable TSWs have not been received.

b. Each TSW set contains the TSWs applicable to a particular combination of customer visibility constraints based on factors such as antenna type, power, and frequency. Each customer may define as many TSW sets as needed, and may define new TSW sets at any time without negotiation with the DSMC.

c. Each SSC either specifies the TSW set applicable to the scheduling of the service specified by that SSC, or specifies that TSWs are not applicable. TSW set is a respecifiable parameter.

10.2.4.4 User Schedule Message

a. SN schedules are transmitted to the MOCs via USMs. A USM consists of a message header followed by one or more service descriptions. The Interface Control Document Between the Network Control Center Data System and the Mission Operations Center, 451-ICD-NCCDS/MOC, provides a detailed description and explanation of the USM and of all other messages exchanged between the DSMC and the MOC.

b. A service description contains all service parameter values needed to initially configure a service. Each service description includes the values of the fixed parameters and the initial values of the reconfigurable parameters required for that service. If more than one service description of the same type is required, they are placed in order as stipulated in the MOC request.

c. The following constraints apply to USMs:

   1. Each USM describes a single event which is for one SUPIDEN, for one TDRS, and for one continuous time period. All of the services within the event are described by the USM.

   2. At least one service must be active at all times during the event.

   3. A single USM can include dissimilar services if they occur during the contiguous time period.

   4. For cross-support, the services for all related TDRSS elements are contained in the same USM for cross-correlation. The constraints for using cross-support services are discussed more thoroughly in Space Network Operations Policy, STDN No. 119.

d. The DSMC transmits the forecast schedule to the MOCs on a weekly basis when it is activated. Subsequent modifications to the active schedule result in schedule messages being immediately transmitted to the appropriate MOCs.

10.2.4.5 Schedule Result Message

a. Schedule Result Messages (SRMs) are sent from the DSMC to the MOC to report the disposition of schedule requests submitted by the MOC. The SRMs report all actions taken by the DSMC, including both automatic processing performed by the NCCDS and manual actions performed by the DSMC SO. In many cases, a single request will result in multiple SRMs.

b. SRMs are also used to report that an event has been deleted. For backwards compatibility, the NCCDS will transmit a Schedule Deletion Notification to baseline MOCs that require this in lieu of the SRM.

10.2.4.6 TDRSS Unscheduled Time

Each MOC receives only those USMs directly relevant to it. USMs do not provide the MOCs with an overview of the SN schedule, and are of little use in attempting to formulate additional schedule requests that will not conflict with other customers' events. To overcome this limitation of the USMs, the DSMC publishes TDRSS Unscheduled Time (TUT) reports on a Web page. These reports are updated periodically and allow the customer to identify time periods during which specific critical SN resources are not in use. Instructions for accessing the TUT Web page are contained in the Interface Control Document Between the Network Control Center Data System and the Mission Operations Center, 451-ICD-NCCDS/MOC.

NOTE

TUT reports are not transmitted via formatted messages. However if a MOC is unable to access TUT reports via the Web page, the DSMC can provide TUT reports via e-mail.

10.2.5 DSMC/FDF Scheduling Interface

10.2.5.1 General

The DSMC/FDF SN scheduling interface is as shown in Figure 10-3. The scheduling information transferred across this interface consists of scheduling aids, acquisition data, and BRTS scheduling data.

10.2.5.2 Scheduling Aids

The scheduling aids for the SN are ground trace predictions generated by the FDF. These ground trace predictions contain one week of customer platform view periods, sun interference, and other information used by both the DSMC and the MOCs to effectively schedule support. The prediction accuracy of these ground traces will be 1-minute epoch time deterioration of the FDF's best estimated orbit. The FDF provides these scheduling aids via a web server rather than via formatted messages. These scheduling aids can be found on the Flight Dynamics Facility Product Center web page, http://mmfd.gsfc.nasa.gov/prod_center/pc_frame_page.htm.

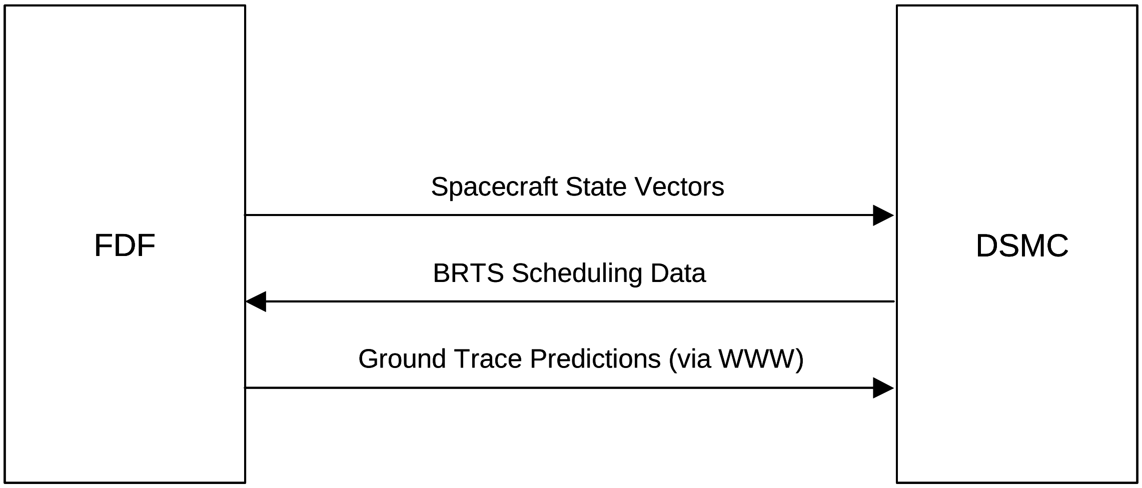


Figure 10-3. DSMC/FDF Scheduling Information Exchange

10.2.5.3 Acquisition Data

Acquisition data messages transmitted by the FDF consist of customer platform state vectors in the Improved Interrange Vector (IIRV) format. The format for IIRVs is provided in section 9.5 of Interface Control Document Between the Network Control Center Data System and the Mission Operations Center, 451-ICD-NCCDS/MOC. State vectors are transmitted to the DSMC on a daily basis with vector epochs spaced at FDF determined intervals. A 2-day projection for each customer is supplied daily. The IIRVs are updated by the FDF in order to maintain the prediction accuracy required for S-band and Ku-band services, while Ka-band tracking services are not available. The FDF also supplies IIRVs for the TDRSs, and for permanent Earth stations.

NOTE

MOCs can provide the DSMC with the IIRVs for their customer platforms rather than having the FDF perform this function for them.

NOTE

The DSMC has the capability to receive IIRVs sent via File Transfer Protocol (FTP) in addition to the capability to receive IIRVs sent via formatted message.

10.2.5.4 BRTS Scheduling

Generic scheduling of the BRTSs is performed by the DSMC with the resultant schedule transmitted to the FDF (which functions as the BRTS MOC). The FDF plans for, and requests scheduling of, BRTS calibrations and special TDRSS test events.

10.2.6 WSC/DSMC Scheduling Interface

10.2.6.1 General

The types of data exchanged between the DSMC and WSC are shown in Figure 10-4. The data transfers relevant to the scheduling process are discussed in paragraphs 10.2.6.2 through 10.2.6.4. Operations Messages (OPMs), TDRSS Service Level Reports (SLRs), and Operations Data Messages (ODMs) are discussed in paragraph 10.3. Refer to Table 10-12 for further information on the real-time message flow between the DSMC and WSC.

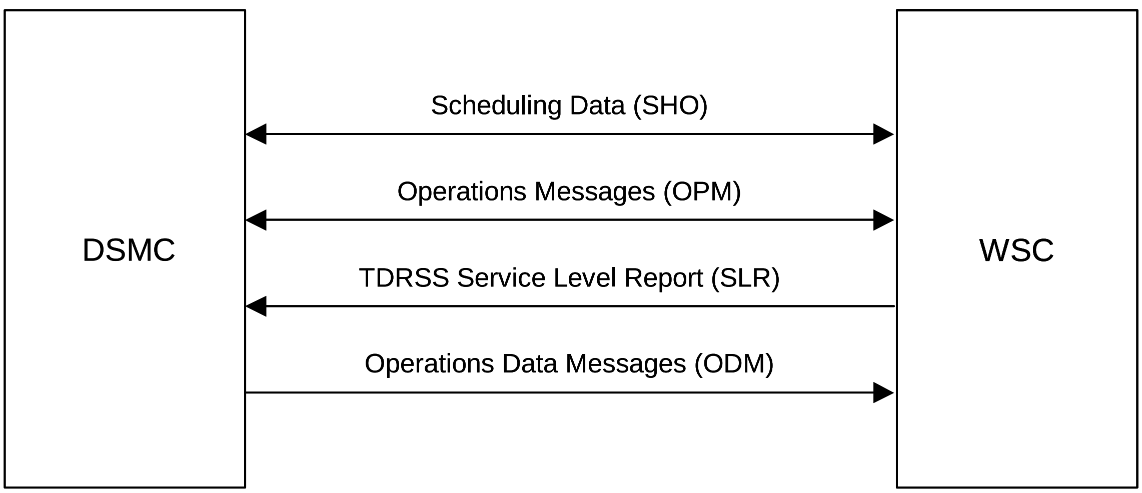


Figure 10-4. DSMC/WSC Data Exchange

10.2.6.2 DSMC/WSC Messages

Two message types are transferred between the DSMC and the WSC that are a direct result of the SN scheduling process: the SHO and the SHO Status Message (OPM, Class 51).

10.2.6.3 SHO

The DSMC transmits a SHO to the WSC to schedule TDRSS services as part of SN support. Two types of electronic SHO messages are used by the DSMC.

a. A Periodic SHO message is used by the DSMC to transmit schedules for customer services whose event start times are equal to or greater than 2 hours and less than 48 hours from the time of SHO receipt at WSC.

b. A Routine SHO message is used by the DSMC to transmit schedules for services whose event start times are equal to or greater than 10 minutes and less than 2 hours from the time of SHO receipt at WSC.

Each SHO is assigned a unique SHO ID number. The SHO contains the fixed and reconfigurable parameters for each TDRSS service (forward, return, tracking and end-to-end test). The SHO completely specifies the service type, subtype, the TDRS to be used, start/stop times, and the initial parameter values to be employed by the TDRSS in establishing the scheduled support services. SHOs will also contain requests for rate-buffering and data quality monitoring. One SHO may contain up to 16 services. The WSC uses SHOs to allocate TDRSS resources in support of the scheduled events. There are many ground rules that govern the structure and transmission of SHOs. A complete listing of these ground rules can be found in paragraphs 2.2.2 and 2.2.3 of the Interface Control Document (ICD) Between the Network Control Center (NCC)/Flight Dynamics Facility (FDF) and the White Sands Complex (WSC), 530-ICD-NCC-FDF/WSC.

10.2.6.4 SHO Status Messages

The SHO Status Message is an OPM (Class 51) transmitted to the DSMC by the WSC in response to received SHOs. It is used to inform the DSMC of the condition (accepted or rejected) of each SHO. If the SHO has been rejected or has been accepted, but some problems exist, a problem code explaining the reason is included in the SHO Status Message. The SHO Status OPM is also used to inform the DSMC when a SHO terminates or is canceled.

10.2.7 DSMC/NEST Scheduling Interface

10.2.7.1 General

a. The DSMC provides the NISN Event Scheduling Terminal (NEST) with schedules applicable to the utilization of NISN resources. Messages sent by the DSMC to the NEST specify the NISN support required at particular times in terms of data rates, data types, data stream ID, sources, and destination. The individual communications service elements of these requests are referred to as data streams.

b. The schedule provided by the DSMC allows NISN personnel to use the NEST to monitor utilization of those NISN resources committed to the SN and to troubleshoot anomalies. The NISN equipment and circuits are primarily data-driven, and do not normally require explicit configuration in response to the schedule; therefore, the NEST does not play a direct role in the configuration or activation of NISN resources. However, under unusual circumstances some NISN equipment requires manual configuration in response to the schedule.

c. The messages that are relevant to scheduling operations and are exchanged between the DSMC and the NEST are listed on Figure 10-5 and are described in paragraphs 10.2.7.2 through 10.2.7.5.

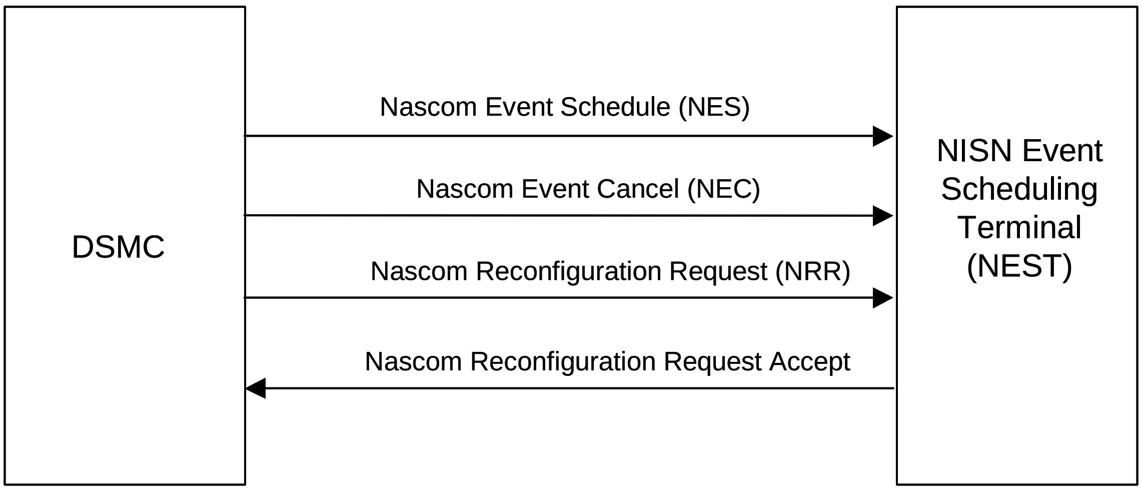


Figure 10-5. DSMC/NEST Scheduling Data Exchange

10.2.7.2 Nascom Event Schedule (NES) Message

At least once daily the DSMC transmits an active schedule to the NEST consisting of no more than 24 hours of support approximately 24 hours in advance of the first event. Each event in this transmission is specified by an individual NES notifying NISN of all scheduled data streams required within the event.

10.2.7.3 Nascom Event Cancel (NEC) Message

This message is used to notify the NEST of the cancellation of an event previously scheduled by the NES Message. The NEC Message may be transmitted at any time prior to or during an event.

10.2.7.4 Nascom Reconfiguration Request (NRR)

Nascom Reconfiguration Requests (NRRs) are sent by the DSMC to notify the NEST that an active event has been reconfigured. The only parameter reconfigurations reported in this message are data stream ID and data rate. Refer to Table 10-13 for real-time message flow between the DSMC and the NEST.

10.2.7.5 Nascom Reconfiguration Request Accept Message

After receipt of an NRR message, the NEST replies with an NRR Accept message.

10.3 SN Real-Time Operations

10.3.1 General

The real-time operations period is the time frame in which the MOC and the SN elements (e.g., DSMC and WSC) perform the necessary activities to support the command, telemetry, and tracking operations of a customer platform. Real-time activities are initiated in a chronological sequence, as specified by the USMs.

10.3.2 Real-Time Operations Functional Overview

Routine SN real-time operations in support of a customer MOC involve the major SN systems (TDRSS and the DSMC) and the two major non-SN NASA elements that support SN operations (NISN and FDF). Table 10-7 provides an overview of real-time operational responsibilities and activities for the DSMC. An overview of the MOC's real-time operational activities is provided in Table 10-8. The real-time operational responsibilities and activities of the FDF and NISN are shown in Table 10-9. WSC operations can be categorized as those occurring just prior to the scheduled support start time, those occurring during the real-time support period, and those occurring post-support. Table 10-10 provides an overview of WSC real-time operational activities.

10.3.3 Real-Time Operations Messages

Instructions, information, and responses between SN elements, non-SN elements that support SN operations, and the customer MOC during SN real-time operations are primarily accomplished by message exchange. These messages are designated by the combination of a two-digit type code together with a two-digit class code (e.g., 03/10). Table 10-11 describes the real-time message flow between the DSMC and the MOC, Table 10-12 describes the real-time message flow between the DSMC and WSC, and Table 10-13 describes real-time message flow between the DSMC and NISN. Information in these tables provides an overview of why a message is sent and the actions that occur when it reaches its destination.

Table 10-7. Real-time Operations Activities Overview for DSMC

System Element	Functional Responsibility	Activity Description	Applicable Timeline
DSMC	Administrative management and coordination of SN	1. Initiating SN real-time operations	1. Ten minutes prior to the start time of the service support period
	Monitoring SN System performance	2. Forwarding Acquisition Failure Notification messages received from WSC to the MOC	2. Whenever received from WSC during a return service
		3. Monitoring SN performance via WSC DQM data in ODMs. When requested, sending UPDs to a MOC	3. The DSMC receives ODMs from the WSC every 5 seconds during the total real-time support duration
		4. Verifying GCMRs from MOCs and generating and transmitting the requested OPMs to the WSC. If necessary, coordinating SN reconfigurations verbally with MOCs and SN resources	4. Any time during the scheduled SHO duration
		5. Processing OPMs from the WSC, coordinating with the MOC if needed, and initiating the proper transactions required by the OPMs	5. Any time during the scheduled SHO duration
		6. Monitoring the implementation status of the OPM by examination of the OPM Status Message (OPM 62) from the WSC	6. Right after OPM transmission
		7. Transmitting nominal state vectors received from the FDF to the WSC	7. During the scheduled service support period if state vector real-time update is required
		8. Canceling an ongoing event when requested by a MOC	8. During the scheduled event support period, as requested by a MOC
		9. Directing data quality monitoring during a customer real-time operation, if necessary	9. Upon customer request or when the SN fails to provide the required quality service to a customer

Table 10-7. Real-time Operations Activities Overview for DSMC (Cont'd)

System Element	Functional Responsibility	Activity Description	Applicable Timeline
		10. Receiving from WSC and transmitting to the MOC return channel time delay measurements	10. Measured at start, stop, and reconfigurations of return service for transmission after the scheduled support period
		11. Receiving from WSC and transmitting to the MOC time transfer measurements	11. Measured a specified number of times during tracking service for transmission after the scheduled support period
		12. Conducting post support debriefing of support elements	12. After completion of scheduled service

Table 10-8. Real-time Operations Activities Overview for MOC

System Element	Functional Responsibility	Activity Description	Applicable Timeline
MOC	Management of customer platform operations	1. Receiving Acquisition Failure Notification messages from the DSMC	1. Shortly after scheduled start of return service, but may also occur anytime during return service
	Monitoring of customer platform performance	2. Initiating of GCM requests	2. Any time during scheduled support period as required
		3. Monitoring customer platform performance data (UPD) and identifying customer platform emergency situations	3. Continuously during scheduled service support duration
		4. Receiving return channel time delay measurement data from the DSMC	4. After completion of return service
		5. Receiving time transfer data from the DSMC	5. After completion of tracking service
		6. Generating post-event reports informing the DSMC of the service quality provided to the MOC	6. After completion of event

Table 10-9. Real-time Operations Activities Overview for FDF and NISN

System Element	Functional Responsibility	Activity Description	Applicable Timeline
FDF	Processing of tracking data	1. Receiving and processing real-time TDMs from WSC	1. During the scheduled tracking period
	Generating orbit and ephemeris data	2. Generating and transmitting real-time state vectors	2. When the transmitted state vectors have epoch time deterioration which exceed the S-band and Ku-band service required values
NISN	Routing data/messages	1. Data-driven configuration and reconfiguration of the communications channels as needed	1. During the duration of customer real-time operations

Table 10-10. Real-time Operations Activities Overview for WSC

System Element	Functional Responsibility	Activity Description	Applicable Timeline
		Prior to the Real-Time Service:	
WSC	Providing TDRSS forward, return, and tracking services to customers Interfacing a TDRS with customer platform based upon specified RF characteristics Responding to DSMC's administrative command and coordination	1. Processing the received SHOs from the DSMC, including: a. Performing syntax checking b. Reserving the required equipment	1. Any time from 10 minutes to 48 hours before service start time
		2. Performing Pre Service Test	2. Up to three minutes prior to service start.
		3. Processing of the DSMC-supplied state vectors	3. Prior to start of service
		4. Generating the TDRS antenna pointing angles (i.e., look angles) and range dynamics data	4. At about 6 minutes prior to service start time
		5. Generating commands to configure the ground equipment and the TDRS	5. At about 1-2 minutes prior to service start time
		6. TDRS antenna acquisition: positioning the scheduled TDRS SA antenna boresight toward the scheduled customer platform	6. Two to 5 minutes prior to the service start time in an SA service SHO

Table 10-10. Real-time Operations Activities Overview for WSC (Cont'd)

System Element	Functional Responsibility	Activity Description	Applicable Timeline
		During the Real-Time service: 7. Initiating Forward, Return, and Tracking services 8. Acquiring a customer platform return service signal: a. Link acquisition sequence for MA return services: (1) PN code acquisition (2) Carrier acquisition (3) Bit synch/Viterbi decoder synch acquisition (4) Data phase ambiguity resolution, if required, after establishment of carrier lock b. Link acquisition sequence for SMA/SSA return services: (1) PN code acquisition, if applicable (2) Carrier acquisition (3) Bit synch/Viterbi decoder synch acquisition (4) Deinterleaver acquisition, if required (5) Data phase and data channel ambiguity resolution and baseband switching, if required, after the establishment of carrier lock	7. At the start of the scheduled support period 8. Acquisition processes start at the beginning of a service (for forward services, the customer platform performs a similar process for the TDRS forward service signal)

Table 10-10. Real-time Operations Activities Overview for WSC (Cont'd)

System Element	Functional Responsibility	Activity Description	Applicable Timeline
		c. Link acquisition sequence for KuSA/KaSA return services: (1) Antenna autotrack pull-in, if applicable (2) PN code acquisition, if applicable (3) Carrier acquisition (4) Bit synch/Viterbi decoder (if applicable) synch acquisition (5) Data phase and data channel ambiguity resolution, and baseband switching, if required, after the establishment of carrier lock Note An acquisition failure message (OPM-63) would be sent to the DSMC and forwarded to the MOC if the WSC did not acquire a customer platform signal within the allocated time duration.	
		9. Notifying the DSMC of entrance and exit into Real-Time Mode (OPM 64)	9. At start and end of real-time maneuver sequence
		10. Processing real-time vectors (type 2, 4, 5, 6, and 7)	10. During the scheduled support periods as required
		11. Determining WSC RCTD, when required. Note RCTD measurements are not provided for services scheduled through GRGT.	11. At the start and stop of a service and at service reconfigurations; for RCTD transmission after the service.
		12. Controlling TDRS antenna operations	12. As needed
		13. Reacquiring a customer platform return service signal if initial acquisition failure or loss of lock occurs	13. Reacquisition activated automatically by the WSC or by a reacquisition OPM from the MOC via the DSMC

Table 10-10. Real-time Operations Activities Overview for WSC (Cont'd)

System Element	Functional Responsibility	Activity Description	Applicable Timeline
		Note An acquisition failure message would be sent to the DSMC and forwarded to the MOC if the WSC did not acquire a customer platform signal within the allocated time duration	
		14. Transmitting ODMs to the DSMC	14. ODMs transmitted every 5 seconds containing all the active services supported by the TDRSS
		15. Processing OPMs, including reconfiguration OPMs sent from the DSMC and initiating proper transactions	15. During the scheduled support period
		15A. Automatically reconfiguring a cross-support return service to coherent mode.	15A. At start time of a forward service associated with the cross-support return service.
		15B. Automatically reconfiguring a cross-support return service to non-coherent mode.	15B. At end time of a forward service associated with the cross-support return service.
		16. Transmitting the required OPMs (except OPM 52) to the DSMC	16. During the scheduled support period
		17. Performing forward channel data presence monitoring (DPM) and return channel data quality monitoring (DQM) as directed by the DSMC	17. During the scheduled support period
		18. Providing rate buffered recording for High Data Rate Service data rates (see Table 3-4) with playback rates of $\leq$ 48 Mbps	18. During the scheduled support period
		19. Providing line outage recording capability to support data recording	19. During the scheduled support period
		Note Line outage recording is provided automatically for the majority of data interfaces, but is not available for some types of data interface (see Table 3-4)	
		20. Transmitting SLRs to the DSMC	20. After detection of equipment failures or upon verbal request.

Table 10-10. Real-time Operations Activities Overview for WSC (Cont'd)

System Element	Functional Responsibility	Activity Description	Applicable Timeline
		21. Transmitting Tracking Data Messages to the FDF	21. Every 5 secs. when requested.
		22. Transmitting time transfer message, OPM 66, to the DSMC, when required	22. Within 1 minute of tracking service termination for which time transfer was requested
		23. Terminating a service or a SHO as scheduled or canceling a SHO as requested by the DSMC	23. At the end of a SHO or at any time during the scheduled SHO duration as requested by a Cancel SHO OPM from the DSMC
		After the Real-Time Service:	
		24. Transmitting RCTD, OPM 52, to the DSMC	24. After service is complete.
		Note	
		RCTD measurements are not provided for services scheduled through GRGT.	
		25. Participating in post event debriefing	25. After event is complete
		26. Transmitting playback of high rate customer return data; transmitting line outage recording data (see Table 3-4)	26. As scheduled; as required

10.4 Customer Platform Emergency Operations

10.4.1 General

SN support to customer platform emergency operations can be divided into two portions: customer platform emergency requests, processing, and implementation; and real-time emergency operations. A thorough description of emergency scheduling and real-time emergency operations is given in sections 10.4.2 and 10.4.3.

The SN capabilities available to support the MOC in customer platform emergency operations consist of the use of SHO schedule requests, OPMs, and the use of the WSC manual commands per DSMC direction, as the situation requires. These capabilities may be used alone or in various combinations to support and resolve a specific operational emergency situation of a customer.

Table 10-11. Real-time Message Flow Between the DSMC and MOCs

Message Category	Message Type/ Class	Message ID	Message Generation Frequency	Message Generation Conditions	Destination System Response
Messages from the DSMC to the MOCs					
User Schedule Messages	94/01	Normal Support – Fixed Schedule		Forecast schedule or routine active period update-- event is fixed	Update schedule database
Note: User schedule messages are normally used during scheduling operations, but may be used during real-time emergency operations	94/02	Premium Support – Fixed Schedule		Schedule add with a lead time of 10 to 45 minutes of event start time – event is fixed	Update schedule database
	94/03	Simulation Support – Fixed Schedule		Forecast schedule or routine active period update – event is fixed	Update schedule database
	94/04	Normal Support – Flexible Schedule		Forecast schedule or routine active period update – event retains flexibility	Update schedule database
	94/05	Simulation Support – Flexible Schedule		Forecast schedule or routine active period update – event retains flexibility	Update schedule database
	99/01	Schedule Delete Notification		Event deleted during active period Note: Applicable only for baseline customers	Update schedule database
	99/02	Schedule Result Message		DSMC reports disposition of MOC submitted schedule request	Update schedule database. Declined request may be changed and resubmitted by MOC
Real-time GCMs	98/01	GCM status		GCMR rejected by either the DSMC or the WSC or accepted by the WSC	
	98/02	GCM disposition		WSC GCM receipt acknowledgment received by DSMC	

Table 10-11. Real-time Message Flow Between the DSMC and MOCs (Cont'd)

Message Category	Message Type/ Class	Message ID	Message Generation Frequency	Message Generation Conditions	Destination System Response
Messages from the DSMC to the MOCs (cont)					
Operations Performance	91/01	UPD	One every 5 seconds during event, when requested	TDRSS customer performance data requested by MOC	
	92/62	Return Channel Time-Delay Measurement		RCTD requested in SHO transmitted to the DSMC by the WSC. Data transmitted by the WSC to the DSMC after termination of scheduled service or when equipment reconfiguration occurs and is sent on to the MOC Note Return Channel Time Delay (RCTD) measurements are not provided for services scheduled through GRGT.	
	92/63	Acquisition Failure Notification		WSC has not achieved initial acquisition or reacquisition of the customer platform return service signal within the predetermined time	MOC may send reacquisition request GCMR (98/03) to the DSMC
	92/66	Time Transfer		Upon termination of a tracking service for which time transfer was requested	

Table 10-11. Real-time Message Flow Between the DSMC and MOCs (Cont'd)

Message Category	Message Type/ Class	Message ID	Message Generation Frequency	Message Generation Conditions	Destination System Response (Note: Descriptions in this column apply to all GCMRs listed on this page)
		Messages from MOCs to the DSMC (cont)			
Real-time GCMRs	98/03 98/04 98/05 98/06 98/07 98/08	Reacquisition Request Reconfiguration Request Forward Link Sweep Request Forward Link EIRP Reconfiguration Request Expanded User Frequency Uncertainty Request Doppler Compensation Inhibit Request		MOC real-time service request	DSMC verifies customer platform eligibility and service availability If valid, the DSMC transmits an OPM to the WSC DSMC sends GCM Disposition to MOC when WSC acknowledges OPM receipt GCM status message is sent to the MOC, if GCMR/OPM is rejected by either DSMC/WSC. GCM status message indicating accept is sent if OPM is accepted by the WSC
Operations Performance	92/04	Performance Data Request		MOC request	DSMC routes WSC ODMs to the appropriate MOC every 5 seconds during event

Table 10-11. Real-time Message Flow Between the DSMC and MOCs (Cont'd)

Message Category	Message Type/ Class	Message ID	Message Generation Frequency	Message Generation Conditions	Destination System Response
Messages from MOCs to the DSMC (cont)					
Specific Schedule Requests	99/10	Specific Schedule Add Request		MOC Scheduling Operator request for normal, simulation, or premium event	99/02 sent to report disposition and 94/xx sent if event is added
Note: User schedule messages are normally used during scheduling operations, but may be used during real-time emergency operations	99/11	Specific Schedule Delete Request		MOC Scheduling Operator request to delete active event, or queued request	99/02 sent to report disposition, 99/01 also sent to baseline customers
	99/12	Specific Schedule Replace Request		MOC Scheduling Operator request to replace active event, or queued request	99/02 sent to report disposition, 94/xx sent if event is added
	99/21	Specific Schedule Alternate Add Request		MOC Scheduling Operator request to link alternate request to a previously queued request	99/02 sent to report disposition, 94/xx sent if event is added
	99/24	Spedific Schedule Wait List Request		MOC Scheduling Operator request to put referenced request on the wait list	99/02 sent to report disposition
	99/28	Schedule Result Request		MOC using TCP/IP sends 99/28 to define communications path for receipt of 99/02 and 94/xx	99/02 and 94/xx sent on communications path defined by 99/28
TDRS Scheduling Windows	99/25	TDRS Scheduling Windows		MOC sends to DSMC to specify customer platform to TDRS visibility	DSMC saves in database, and applies to scheduling

Table 10-12. Real-time Message Flow Between the DSMC and the WSC

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the DSMC to the WSC						
OPM 01 Special Instruction or Request	03/01	Used in message exchange between controllers Not used in automatic processing/control		This message is used to send free-form alphanumeric text from the DSMC to WSC	No processing required WSC prints this message and displays it on a TOCC console	
OPM-02 Reacquisition Request	03/02	Real-time control message		Initial link acquisition failure	DSMC reformats and validates the MOC GCMR (98/03)	WSC response time is up to 20 seconds (forward) and 10 seconds (return of OPM receipt and acceptance for all services
				Link unlocked		WSC sends an OPM 63 (Acquisition Failure Notification) to the DSMC if the acquisition process fails
				Link acquisition failure during a customer platform real-time configuration	WSC verifies and validates the OPM and initiates the reacquisition process. It should be noted for coherent service mode, a forward reacquisition will cause both forward and return services to be reacquired	WSC sends an OPM status message (OPM 62) upon successful reacquisition completion

Table 10-12. Real-time Message Flow Between the DSMC and the WSC (Cont'd)

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the DSMC to the WSC (cont.)						
<u>OPM 03</u> Customer Reconfiguration Request	03/03	Real-time control message		A MOC transmits a TDRSS reconfiguration request to the WSC, via a GCMR to the DSMC, if there is a need to reconfigure the WSC and TDRS equipment supporting its customer platform	DSMC reformats and validates the MOC reconfiguration request (98/04) and transmits an OPM (03/03) to WSC	WSC response time is up to 35 seconds of OPM receipt and acceptance for all services
					DSMC responds to a GCM from a MOC with GCM status (98/01) and GCM disposition (98/02) messages	WSC will respond to the OPM 03 with an OPM 62 after successful completion of the reconfiguration or a message rejection if the message is incomplete or invalid
					WSC verifies and validates the OPM and processes and implements the OPM if legal	
<u>OPM 04</u> Forward Link Sweep Request	03/04	Real-time control message		Used as an acquisition aid when customer platform receiver acquisition failure is suspected because customer platform receiver frequency differs from expected values. Used in both initial and reacquisition situations	DSMC reformats and validates the MOC-generated forward link sweep request (98/05) and transmits an OPM (03/04) to the WSC	WSC initiates the forward link sweep within 10 seconds of OPM receipt and acceptance
					WSC verifies and validates the OPM and initiates the forward link sweep process	WSC will respond to the OPM 04 with on OPM 62 confirming that the sweep has started or a message is incomplete or invalid

Table 10-12. Real-time Message Flow Between the DSMC and the WSC (Cont'd)

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the DSMC to the WSC (cont.)						
OPM 06 Forward Service EIRP Reconfiguration Request	03/06	Real-time control message		This OPM is used to set the TDRS SSA and KaSA/KuSA EIRP to normal or high power as the situation requires	DSMC reformats and validates the MOC-generated forward link EIRP reconfiguration request (98/06) and transmits an OPM (03/06) to WSC WSC validates, processes, and implements the OPM by changing the TDRS onboard power mode	WSC response time is up to 10 seconds of OPM receipt and acceptance for all services WSC will respond to the OPM 06 with an OPM 62 acknowledging receipt of an OPM without detecting errors or a message rejection if the message is incomplete or invalid
OPM 07 Expanded Customer Frequency Uncertainty Request	03/07	Real-time control message		This message is generated when the MOC cannot accurately predict the customer platform transmit frequency for DG1 mode 2 and DG2 (non-coherent) operation	DSMC reformats and validates the MOC-generated expanded customer platform transmit frequency uncertainty request (98/07) and transmits an OPM (03/07) to WSC WSC validates and processes the OPM and initiates the expansion of the return service frequency area examined	WSC response time is up to 5 seconds of PM acceptance for all services. WSC will respond to the OPM 07 with an OPM 62 acceptance status upon frequency expansion initiation or an OPM 62 reject if the message is incomplete or invalid

Table 10-12. Real-time Message Flow Between the DSMC and the WSC (Cont'd)

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the DSMC to the WSC (cont.)						
<u>OPM 10 or 15</u> Spacecraft State Vector	03/10 or 15	Real-time or non real-time message	Daily or more often, if necessary, for each customer platform	This message is used to transmit customer platform state vector data to WSC prior to the scheduled service support period start time	The data contents of the message are generated by FDF The message originates at FDF and is transmitted to the DSMC for retransmission to WSC	WSC will respond to the OPM 10 message with an OPM 61 state vector rejection message if the vector is found to be unusable OPM 64 will be sent upon entrance and exit of the real-time mode. OPM 64 will be provided for type 2, 4, 5, 6, 7 state vectors received within 6 minutes prior to service or during service with epochs to be applied before service termination
<u>OPM 11</u> Doppler Compensation Inhibit Request	03/11	Real-time control message		Prior to the beginning of a two-way tracking service	DSMC reformats and verifies the MOC-originated Doppler compensation inhibit request (98/08) and transmits an OPM (03/11) to WSC WSC validates and processes the OPM and initiates inhibition of the Doppler compensation on the referenced forward service	WSC will initiate Doppler Compensation Inhibit within 10 seconds of receipt of OPM 11 and fix the forward carrier frequency within 20 seconds after receipt of OPM 11. WSC sends an OPM status message (OPM 62) after successful initiation of the Doppler Inhibit

Table 10-12. Real-time Message Flow Between the DSMC and the WSC (Cont'd)

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the DSMC to the WSC (cont.)						
OPM 12 Cancel SHO Request	03/12	Real-time or non real-time message		When it is necessary for the DSMC to request cancellation of either an on-going or an upcoming SHO	DSMC transmits a Cancel SHO OPM (03/12) to WSC	WSC sends an OPM status Message (OPM 62) upon acceptance of the Cancel SHO OPM
					WSC validates the message and cancels the specified SHO	WSC sends and OPM 51 indicating referenced SHO was successfully deleted from the WSC database
OPM 13 TDRS Maneuver Approval	03/13	Non real-time message	As required	DSMC transmits approval/ disapproval in response to a TDRS Maneuver Request, OPM 59, from the WSC	Manual – operationally thisis handled via e-mail	WSC may initiate TDRS maneuver upon receipt of approval from DSMC
OPM 18 Δt Adjustment	03/18	Real-time or non real-time message		DSMC uses this message to adjust the epoch time parameter within stationary state vectors (launch holds)	DSMC formats and transmits the message to WSC prior to epoch reference time	WSC system response time is up to 30 seconds of OPM receipt and acceptance or at the new epoch reference time, whichever is later
				Not used for orbit correction		WSC will respond to the DSMC with an OPM 65, Δt adjustment rejection to a state vector rejection message, if appropriate
						WSC may send OPM 64 real-time mode entry/exit, as appropriate

Table 10-12. Real-time Message Flow Between the DSMC and the WSC (Cont'd)

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the WSC to the DSMC						
OPM 51 SHO Status	03/51	Real-time or non real-time message	Daily at SHO transmissions if status changes	Used by the WSC to inform the DSMC of the status of a SHO	NCCDS processes the message, alerts the operators if problems exist	Problems handled by operators
OPM 52 Return Channel Time Delay	03/52	Real-time data message (not a control message)	MOC initiated request. Not a re-configurable parameter	When a SHO includes a request for return service time delay data, the return channel time delay data will be obtained at the start and stop of the return service and at service reconfigurations. An OPM (03/52) is used to send DSMC the data after termination of the return service	DSMC receives and reformats the message and sends it to the appropriate MOC	
OPM 53 Preventive Maintenance Request	03/53		1 week in advance of the preventive maintenance date	This message will be used to send free-form alpha-numeric text from WSC to the DSMC	DSMC receives and verifies the message NCCDS alerts the DSMC operator The DSMC operator will block the affected resources to keep them from being scheduled for customer support	

Table 10-12. Real-time Message Flow Between the DSMC and the WSC (Cont'd)

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the WSC to the DSMC (cont.)						
OPM 54 Special Request or Information	03/54	Used in message exchange between controllers Not used in automatic processing/control		This message will be used to send free-form alpha-numeric text from WSC to the DSMC Operationally, an OPM 54 is used to request preventative maintenance	DSMC receives and verifies the message NCCDS alerts the DSMC operator	
OPM 57 Service Termination	03/57	Real-time report message		This message is sent from WSC to the DSMC for notification of the termination of a service	DSMC logs the data	
OPM 59 TDRS Maneuver Request	03/59			When the WSC desires to perform a TDRS maneuver which might have an impact on providing service, advance approval is requested from the DSMC	DSMC receives and validates the OPM Operationally this is handled via e-mail. NCCDS alerts the DSMC operator DSMC operator processes the request and attempts to resolve any possible impact during the requested maneuver duration	DSMC responds to the WSC with an OPM 13, TDRS maneuver approval message, which will either grant or deny WSC permission for the TDRS maneuver

Table 10-12. Real-time Message Flow Between the DSMC and the WSC (Cont'd)

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the WSC to the DSMC (cont.)						
<u>OPM 61</u> Spacecraft State Vector Rejection	03/61	Near real-time or non-real-time message reporting the rejection of an OPM 10 or 15 message		Before propagating the ephemeris data from a received state vector, WSC performs the required validity checks. If any of these DSMC-WSC messages fail validity checks, this rejection message is sent from the WSC to the DSMC	Receives and validates the OPM NCCDS alerts the DSMC operator	DSMC operator may respond to the WSC with a new OPM 10, or 15 message
<u>OPM 62</u> OPM Status	03/62	Real-time or non-real-time message	One for each OPM	OPMs received by WSC from DSMC will be checked for validity. This message is then used by the WSC to inform the DSMC that either the OPM has been accepted, or rejected as a result of the validity checks detecting an erroneous OPM If an OPM is rejected, OPM 62 will be sent immediately. If accepted, OPM 62 will be sent acknowledging receipt for OPMs 6 and 12 and OPM 62 will be sent upon OPM implementation for OPMs 2, 3, 4, 7, and 11.	The NCCDS receives and validates the OPM and notifies the DSMC operator if the DSMC OPM has been rejected For an DSMC OPM that has been rejected, the DSMC initiates the required handling to correct the problem code error	For an DSMC OPM that has been rejected, the DSMC or the impacted MOC corrects the error and the DSMC retransmits the corrected OPM to WSC

Table 10-12. Real-time Message Flow Between the DSMC and the WSC (Cont'd)

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the WSC to the DSMC (cont.)						
OPM 64 Real-Time Mode Notification	03/64		Enter Real-Time Mode upon receipt of any of the following messages less than 6 minutes prior to the start of service or during service: a. Delta-T message b. Type 1 or 8 vector with an epoch prior to the end of service c. Type 2, 4, 5, 6, or 7 vector as part of a maneuver sequence and with an epoch time in the future prior to the end of service. WSC must have at least 2 maneuver vectors with future epoch times	This message is used by the WSC to inform the DSMC that the WSC has entered or exited the Real-Time Mode	The NCCDS receives and validates the OPM and notifies the DSMC operator	Upon receipt of message indicating entry into real-time mode, the NCCDS refrains from initiating transmission of other data that could require real-time mode processing until WSC responds with a message indicating that it has exited from real-time mode
OPM 65 Δt Adjustment Rejection	03/65	Near real-time or non-real time message reporting the rejection of an OPM 18 message		WSC uses this message to advise the DSMC that a requested Δt adjustment has not been implemented	NCCDS alerts the DSMC operator DSMC operator initiates processing to handle the problem	DSMC may retransmit the corrected Δt adjustment (03/18) to WSC

Table 10-12. Real-time Message Flow Between the DSMC and the WSC (Cont'd)

Message ID	Message Type/ Class	Message Length and Operational Characteristics	Message Generation Frequency	Message Generation Conditions	Required Processing	Destination System Response
Messages from the WSC to the DSMC (cont.)						
<u>OPM 66</u> Time Transfer Data	03/66	Variable length dependent on number, n, of time transfer samples		Transmitted to DSMC within 1 minute of tracking service termination for which time transfer was requested in the SHO	DSMC receives and reformats the message and sends it to the appropriate MOC	
<u>Service Level Requests (SLRs)</u>	04/NA (note)	SLRs with ID numbers 1 to 4,999,999 to 1 are a result of equipment status change. SLRs with ID numbers 5,000,000 to 9,999,999 to 5,000,000 are sent in response to DSMC request		Upon verbal request from the DSMC or upon change in any reported parameter within 15 minutes of change SLR information is also sent via e-mail	For resources reported as unavailable, the DSMC operator will block the affected resources to keep them from being scheduled for user support	
<u>Operations Data Messages (ODMs)</u> SA/SMAR MA/SMAF End-to-End Test	05/NA (note) 06/NA (note) 07/NA (note)	Real-time operations report	One every 5 seconds during active event	Separate ODMs are sent for SA/SMAR, MA/SMAF, and end-to-end test services for each TDRS whenever service is ongoing	ODMs are reformatted as UPD messages and routed to appropriate MOC when requested	Route TDRSS customer performance data message to appropriate MOC
Note: Message class information not applicable to SLRs and ODMs						

Table 10-13. Real-time Message Flow Between the DSMC and NISN

Message ID	Message Type/ Class	Message Length	Message Generation Conditions	Message Destination System Response
Messages between the DSMC and NEST				
Nascom Event Schedule	90/01	1 to 6 blocks	Daily schedule transmission	Information used by NISN to monitor resource utilization
Nascom Event Cancel	90/02	1 block	To cancel an accepted support event One message per event as needed	Information used by NISN to monitor resource utilization
Nascom Event Schedule Update	90/04	1 to 6 blocks	Event added to daily schedule after normal transmission	Information used by NISN to monitor resource utilization
Nascom Event Emergency Schedule	90/05	1 to 6 blocks	Event added with a lead time of 5 to 45 minutes of event start time	Information used by NISN to monitor resource utilization
Nascom Reconfiguration Request	90/06	1 to 2 blocks	Change to requirements for ongoing event	Information used by NISN to monitor resource utilization
Nascom Reconfiguration Request Accept	90/07	1 blocks	NEST always responds to 90/06 with Accept	Absence of this message will cause alert to DSMC operator.

10.4.2 Emergency Scheduling

10.4.2.1 Customer Platform Emergency Requests for SN Support

a. Emergency scheduling spans the period from the point a MOC declares a customer platform emergency to the DSMC to implementation of the SHO by the WSC. A Routine SHO message is transmitted if the required event start time is less than 2 hours from the time of SHO receipt at WSC.

b. The MOC requests emergency support by notifying the DSMC of the nature of the declared emergency, desired start time, services required, and expected duration of the support. Customer platform emergency requests for SN support are submitted as Schedule Add Requests with the customer priority set to 1 to indicate that the request is for emergency support. If the start time is less than 10 minutes away, manual intervention by the DSMC operator will be necessary.

10.4.2.2 DSMC Processing of a Customer Platform Emergency

a. The procedure for processing the customer platform emergency request is similar to the regular scheduling process except for any unresolvable scheduling conflict. The DSMC SO receives an alert from the NCCDS when the request is either successfully processed or rejected. If the scheduling request is rejected, the message from the NCCDS notifies the DSMC SO of the details of the conflict. The DSMC SO attempts to resolve the conflict by individual discussions with each impacted MOC to determine if its scheduled service support period can be terminated or delayed. If these conflict resolution discussions are not successful, the DSMC makes the scheduling decisions. When necessary, the DSMC SO deletes conflicting events. This results in Schedule Result Messages being transmitted (refer to paragraph 10.2.4.5) to each impacted MOC to notify them of the deletions. The DSMC SO also informs the MOC initiating the customer platform emergency request of appropriate details of the conflict resolution. Based upon the information supplied to that MOC by the DSMC SO, it prepares and transmits a new Schedule Add Request to the NCCDS for processing. However if the changes needed to the original request are relatively simple, the DSMC SO may edit the request rather than requiring the MOC to submit a new request.

b. If the scheduling request causes no conflict, the NCCDS automatically approves it, generates a SHO, and transmits that SHO to the WSC. The DSMC also generates and transmits a Schedule Result Message to the MOC and the schedules to other affected SN elements.

c. The DSMC tests for conflicts in allocating services and, if a conflict exists, works with the MOC to resolve the conflict. The following procedures apply:

    1. The NCCDS automatically attempts to resolve the conflict by shifting events within MOC prescribed tolerances.

2. If the conflict resolution attempt is unsuccessful, the NCCDS sends a Schedule Result Message to the requesting MOC advising that the request has been declined.

3. After evaluating the Schedule Result Message, the customer MOC may contact the DSMC SO for further assistance. The DSMC scheduling operators perform the necessary conflict analysis.

4. If the DSMC SO approves the request, he deletes all conflicting events.

5. If the request is denied, the original schedule remains unaffected.

6. The requester and all those affected are notified of the DSMC's final decision via either a schedule update, verbal communications, or a Schedule Result Message as appropriate at the time the decision is made.

7. All schedule requests, including customer platform emergency requests, must specify an event start time. The resulting schedule messages are sent immediately to NISN, the WSC, and the impacted MOCs.

10.4.2.3 WSC Processing of the Customer Platform Emergency SHO

Once the customer platform emergency SHO arrives at the WSC, the following WSC processing takes place within 5 minutes of receipt of the SHO:

a. Start times for all services called out by the SHO are generated. Checks are made that service durations are at least 60 seconds but not greater than 24 hours.

b. A resource check is made and the equipment required is reserved. If the SHO is accepted, a SHO Status OPM is transmitted to the DSMC indicating acceptance of the SHO. If the SHO is rejected, a SHO Status OPM is transmitted to the DSMC indicating rejection of the SHO. This message contains an error code giving the reason for rejection. It is expected that there will be only minimal instances in which the WSC rejects the SHO. Based upon the specific error code, the DSMC scheduling operator will continue attempts to obtain support.

10.4.3 Real-Time Customer Platform Emergency Operations

As far as the WSC and the DSMC are concerned, the use and processing of the MOC reconfiguration GCMRs is the same for both normal and emergency real-time operations. During a customer platform emergency operation, the MOC may send a series of command messages to its customer platform to perform the troubleshooting and procedures necessary to correct the emergency condition. These messages could include channel data rate changes and may require corresponding changes within the TDRSS channel configurations. A MOC can issue a GCMR to the DSMC requesting a TDRSS real-time reconfiguration to support such unplanned channel data rate changes. After receipt of the corresponding OPM from the DSMC, the WSC will nominally respond and complete the requested reconfiguration in less than 35 seconds, (refer to Table 10-12 under "Messages from the DSMC to the WSC" for additional constraints). An OPM 62 status will be sent by WSC upon reconfiguration GCM completion.